PROGRESS REPORT

ON

NASA MULTIDISCIPLINARY GRANT 44-005-021

College of Business Administration
University of Houston
January, 1970

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As the previous progress reports regarding activity under this grant have suggested, the emphasis within the College of Business Administration has been on the development of a graduate program in Science and Technology Management (STM). Largely as a result of the comparative curriculum study funded by the NASA grant, the College has developed and proposed to the Coordinating Board of the Texas College and University System a Master of Science in Administration program (M.S.A.)(See Attachment A).

The STM Option in the M.S.A. Program

Much of the general systems and technology flavor of an STM program is embodied in the core curriculum of the M.S.A. However, it is contemplated that further intensification will be provided through a specialty option in STM.

The focus of the specialty option is on the micro-management of complex, technology-based organizations in both the private and public sectors, as opposed to the macro-management of society's scientific knowledge and resources. The macro-management aspects of science and technology are treated at the appropriate level of intensity in the M.S.A. core curriculum (see the following courses: MSA 633: Management and the Socio-Technical Process; MSA 611: Seminar in Contemporary Issues, and MSA 635: Values and Innovations in Management Systems.)

In order to provide the appropriate micro-management education, the College intends to select students who have natural science and engineering undergraduate education, and who are committed to the practice of managing technological tasks, or research and development in the management of science and technology. The selection process is considered to be an integral part of the education process, and those admitted to the STM option would be expected to have high potential for continuation to the doctoral level in administrative sciences.

The STM option would include three special courses in: (1) the systems development and design process, (2) the management of the people and tasks in science and technology, and (3) the systems marketing and contracting process.

1. The systems development and design process has become a unique discipline, with its procedures and analytical tools developed from a combination of mathematics, economics, engineering, and the behavioral sciences. The decision process by which environmental data are transformed into a systems requirement has become highly sophisticated, with the requirement that systems effectiveness and proposed systems costs be made quantifiable and capable of operational definition. At the same time, human wisdom and judgment is codified at the final decision stage. After the requirement has been made firm, the processes of systems engineering, configuration design

and management, data management, and cost, schedule and technical management are brought into play, and integrated by means of systems program direction. These processes are to be taught by means of participative techniques, employing operational and computer simulation.

2. The management of the people and tasks in the scientific and technological realms requires the application of a combination of quantitative techniques and interpersonal and organizational skills. The rarity of the technologically and scientifically trained people who are required for the carrying out of the tasks, their motivational patterns which are different from those of most human beings, the high degree of conceptual abstraction involved in most science and technical tasks, the low probability of success involved in some tasks, along with the very high investments of funds needed for both high risk and highly probably successful tasks, makes the management process different from that involved in less innovative activities.

Research-based data and some concepts now exist for unifying the field, and there are participative exercises available for teaching skills involved. The course would be a combination of study of previous research, an active project to produce research-based learning, and exercises for the development of skills in the strategy and tactics of research and development organization management.

3. The science and technology systems marketing and contracting process has become a specialized field. The knowledge of the current environment in public and private sectors begins with a study of national goals and economic systems, in the courses referred to in the M.S.A. core curriculum. This course would begin with considerations of technological and environmental forecasting, continue with governmental and private socio-technical marketing and acquisition systems, and proceed to detailed study of the data on pricing and negotiation, contracting, and measurement of technological performance. Simulated tasks would be employed for pedagogical purposes, and research data on bargaining and negotiating within private and public institutions would be a base for learning.

Research Support Through Center for Management Studies and Analysis (CEMSA)

To provide research support for the STM option, as well as for the rest of the M.S.A. program, the College has established the Center for Management Studies and Analysis (CEMSA; see Attachment B).

CEMSA is already operating and should be fully capable of providing research assistantships and project experience to the graduate students and faculty involved in the STM option of the M.S.A. when those programs commence in the fall of 1971.

Continuing Activity Under the Grant

The prospect of greatly expanded interaction between the College and NASA, expecially NASA/MSC, has played a large part in attracting STM-oriented faculty to the College during the Past year. Dr. John

Zuckerman, Chairman of the Department of Behavioral Management Science, Dr. Edwin G. Triner, Chairman of Production and Logistics Management and Director of CEMSA, and Dr. Albert Arcus and Dr. Benjamin Ostrofsky, both Professors of Production and Logistics Management, are among those who will play key roles in shaping and developing expanded relationships between the College and NASA. Their personal data sheets are included in Attachment C.

ATTACHMENT A

M.S.A. PROGRAM

A PROPOSAL FOR A MASTER OF SCIENCE DEGREE IN ADMINISTRATION

SUBMITTED TO

COORDINATING BOARD, TEXAS COLLEGE AND UNIVERSITY SYSTEMS

BY

UNIVERSITY OF HOUSTON

OCTOBER 1969

I. DESCRIPTION OF PROPOSED PROGRAM

I.

1) What is the title and nature of the proposed program?

a) Title of Program

Master of Science in Administration

b) Nature of proposed program

A systems-oriented program to enable the graduate to function at any managerial level in complex organizations whether in business, government, or other crucial sectors of society.

2) Degree or Certificate Contemplated

Master of Science in Administration (M.S.A.)

I.

3) List the course offerings to comprise the program. Which of these courses will be new ones?

With the exception of the elective courses, all of the courses in the proposed MSA program will be new. The twelve hours of electives which are allowed in the final two semesters of study may be selected from courses offered either in the College of Business Administration or in any other college. The emphasis in the elective sequence is upon flexibility and relevance to the student's interests. All twelve hours may be taken in one area of interest or the work may be divided into as many as three separate areas, as long as at least six hours are taken in one area. The elective sequence shall be approved by the student's advisory committee (See section I, 5).

It is expected that through this elective sequence the program will produce students who will pursue administrative careers not only in business but also in the management of other complex organizations such as hospitals, clinics, fine arts institutions and government agencies. The required course work is designed to provide broad administrative skills, with the elective sequence serving to develop interest and knowledge in specific areas of application.

The non-elective courses to be included in the curriculum consist of:

MSA 631: Human Behavior in Management Systems
Cr. 3. (3-0). Prerequisite: Basic Psychology or Sociology Course.
Human behavior in the management environment. Analysis of the organizational environment and administrative role emphasizing the motivational and attitudinal dynamics of inter-personal relationships.

MSA 661*: Quantitative Methods for Planning and Control I
Cr. 6. (6-0). Prerequisites: Knowledge of differential and integral calculus, linear algebra, computer programming.
Fundamental tools and theory for planning and control in an administrative environment, including concepts from statistics, accounting, systems analysis, and other quantitative management methods.

MSA 632: Systems and Organization Theory
Cr. 3. (3-0).
The system development process, its logic and relationships to methods of systems analysis, and to the study of complex organizations and social systems.

MSA 633: Management and the Socio-technical Process
Cr. 3. (3-0).
Evolution and development of technology, including cultural values and their interface with social change and economic development; management of problems arising from conflict and change.

MSA 662*: Quantitative Methods for Planning and Control II
Cr. 6. (6-0). Prerequisites: MSA 661.
Continuation of topics in MSA 661.

MSA 691*: Introduction to the Functional Process
Cr. 9. (9-0). Prerequisite: completion of first semester of MSA program.
Analysis of organizational inputs and output. Synthesis of concepts from the economic theory of the firm, marketing, production, logistics, and finance.

MSA 663*: Advanced Topics in the Functional Process
Cr. 6. (6-0). Prerequisite: completion of second semester of MSA program, including MSA 641.
Further integrated development of topics in functional areas of managerial economics, marketing, production, logistics, and finance.

MSA 634: Economics and Public Policy
Cr. 3. (3-0). Prerequisite: completion of second semester of MSA program.
Macroeconomic analysis, monetary and fiscal policy, and other selected aspects of public economic policy.

MSA 611: Seminar in Contemporary Issues I
Cr. 1. (1-0).
Examination of current social and public policy issues, with emphasis on responsibilities and opportunities for the participation of managers in shaping the social environment.

MSA 664:* Integrated Management Simulation
Cr. 6. (6-0). Prerequisite: completion of third semester of MSA program.
Further application of concepts and techniques to complex, simulated management decision-making situations.

MSA 635: Values and Innovations in Management Systems
Cr. 3. (3-0). Prerequisite: completion of third semester of MSA program.
Value systems and relationships to decision making by individuals and groups. Study of interactions of culture and innovation, emphasizing communications problems.

MSA 612: Seminar in Contemporary Issues II
Cr. 1. (1-0). Prerequisite: completion of third semester of MSA program.
Continuation of MSA 611.

* Each of these courses carries six hours of credit, with the exception of MSA 691 which carries nine. If necessary to meet the requirements of the Office of the Registrar, each of them may be listed in three-hour segments using letters to further identify each segment. We would of course require in such a case that all segments of a given course be taken simultaneously.

EXAMPLE: MSA 691A, 691B, 691C: Introduction to the Functional Process
Cr. 3 each. All three courses MUST be taken simultaneously and will be graded homogeneously; thus, total credit 9. (9-0). Prerequisite: completion of first semester of MSA program.
Analysis of organizational inputs and outputs. Synthesis of concepts from the economic theory of the firm, marketing, production, logistics, and finance.

I.

4) Outline a semester-by-semester curriculum for the proposed program.

The success of the proposed program requires that each entering group of students take the same courses in the same sequence. Consequently, all students will complete their course work in the following sequence:

First Year - First Semester		First Year - Second Semester	
Course	Hours	Course	Hours
Human Behavior in Management Systems	3	Quantitative Methods for Planning and Control II	6
Quantitative Methods for Planning and Control I	6	Introduction to the Functional Process	9
Systems and Organization Theory	3		15
Management and the Socio-technical Process	3		
	15		
Second Year - First Semester		**Second Year - Second Semester**	
Course	Hours	Course	Hours
Advanced Topics in the Functional Process	6	Integrated Management Simulation	6
Economics and Public Policy	3	Values and Innovation in Management Systems	3
Electives	6	Electives	6
Seminar in Contemporary Issues I	1	Seminar in Contemporary Issues I	1
	16		16

Total number of credit hours in MBA program = 62

MSA PROGRAM SCHEME

Area	Semester I	Hrs	Semester 2	Hrs	Semester 3	Hrs	Semester 4	Hrs	Total Hours
Foundations of Administrative Process	Human Behavior in Management Systems Systems and Organization Theory Quantitative Methods for Planning and Control I	3 3 6	Quantitative Methods for Planning and Control II	6					18
Functional Process			Introduction to the Functional Process	9	Advanced Topics in Functional Process	6	Integrated Management Simulation	6	21
Environmental Analysis	Management and the Socio-technical Process	3			Economics and Public Policy	3	Values and Innovation in Management Systems	3	9
Electives					Electives	6	Electives	6	12
Seminar					Seminar in Contempo-rary Issues I	1	Seminar in Contempo-rary Issues II	1	2
Total Hours		15		15		16		16	62

I.

5) What special requirements will be enforced? If a graduate degree is contemplated, is a thesis required? If not, what will be substituted?

Admissions. Admissions will be limited to exceptionally qualified candiates. Admission standards will normally include a 3.0 (B) average on previous graduate or undergraduate work and a score of at least 500 on the ATGSB. Acceptance will be granted by an Admissions Committee.

Advisory Committee. The candidate will be guided in his program by a committee composed of the professors teaching the core courses and other faculty representing the major elective sequence.

Thesis Substitute. No thesis will be required. The role traditionally performed by the thesis will be handled by the six hour course in Integrated Management Simulation. This capstone course will require the student to demonstrate a high level of proficiency in the use of systems analysis, which will have been emphasized during his first three semesters.

Internship. During the first summer following his entrance into the MSA program, each student will be encouraged to gain experience in real administrative situations. This experience will be gained through an internship in a business organization, a hospital administrative office or some other organizational setting appropriate to the student's interests. The internships will be arranged by the Director of the MSA program in consultation with the student and his professors.

I.

6) Has the proposed program or one similar to it been offered in this institution at any time prior to this request?

There is not nor has there ever been a program similar to the proposed Master of Science in Administration offered at the University of Houston. At the present time the College of Business Administration offers at the graduate level the Master of Business Administration, the Master of Accountancy, and the Doctor of Philosophy in Business Administration. The Department of Economics offers the Master of Arts and the Doctor of Philosophy degrees. The essential difference between the proposed degree and the currently offered MBA is made clear in Section I, 8 of this document.

I.

7) How many similar programs are offered elsewhere in Texas, and where?

There are no similar programs being offered in Texas or the Southwest. Geographically, the nearest program which most closely approximates the proposed program is the Master of Science in Industrial Administration offered at the Krannert School of Industrial Administration, Purdue University, Lafayette, Indiana. Others are offered at the Graduate School of Industrial Administration, Carnegie-Mellon University, Pittsburgh, and at the Sloan School of Management, M.I.T., Boston.

I.

8) Justify the need for the proposed program.

The role of the administrator in America today is evolving. Advances in science and technology have modified the goals, tasks, and techniques of society. As the parts of the economy and other societal sectors become increasingly interdependent, so must the parts of human organizations be further and more effectively integrated. The organization must be seen as a system composed of linked sub-systems, and it must be recognized that managing a complex flow system is different conceptually from managing an organization consisting of primarily discrete subunits which require, or at least typically have had, only loose affiliation. Subsystems must be coordinated to produce an integrated flow of information, materials, or energy.

The manager of such a system must be able to solve complexes of simultaneous, nested problems. He must be able to understand how one decision is either affected by or affects numerous interrelated processes which have both temporal and structural dimensions. His perspective must be that of systems flow, not of static structure. His conceptual tools of analysis must be greater in number, complexity, and abstraction than ever before. Therefore, his education must be different.

The University of Houston College of Business Administration has been in a stage of transition during the past several years in an effort to meet these challenging new demands. It has emerged from a school that taught techniques and vocationally oriented business skills to one that emphasizes various scientific

disciplines applied to the business setting. Concepts rather than techniques are now taught to provide the student with the ability to generalize his learning experience to the ever-changing needs of most enterprises. Evidence for this program revitalization can be seen in the revamped curricula at both the BBA and MBA levels, as well as in the recent college departmental reorganization and in the type of faculty recruited. The College can be said to be in its second generation and it is expected that its graduates will satisfy the needs of many complex organizations for years to come. Since the graduates have not been equipped with a repertoire of specific techniques but with an adaptive conceptual frame of reference which has the capability of rapid growth, they should be able to cope with the changes that will characterize many enterprises during their careers.

However, even the current types of graduates are not fully capable of satisfying all the systems-oriented administrative needs of the more complex science-based industries. Today's MBA graduates are needed for many positions of responsibility, but there is a rapidly growing need for systems oriented problem solvers whose perspectives permit them to see and understand relationships between functions and processes. Enterprises must now recruit these select graduates in a few schools such as Carnegie-Mellon, Harvard, M.I.T., Krannert School at Purdue and a very few other prestigious institutions. In the Southwest there is no school producing such graduates, despite the growing need for this type of person.

If the College of Business Administration at the University of Houston is to be truly responsive to the total needs of the region, it must produce graduates of both types.

The College will initiate its doctoral program in the fall of 1969. This program serves a third highly critical need; that of the development of research oriented students with a terminal degree. These students, for the most part, may be expected to select academic and research positions rather than administrative positions.

The College is often requested to initiate new degree programs for special need areas. For example, there are growing administrative demands in many organizations in non-business fields such as government, medicine, the fine arts, and recreation. It is impossible, of course, to offer degree programs in all of these areas. Thus it may be concluded that there is a need for a program which develops skills that are administrative in nature but are not restricted to business applications alone. The proposed program is of this nature. It is designed to provide the students with generalizable knowledge of administration that is equally applicable in organizing and operating a government agency, a private firm, a hospital, or a university.

Moreover, the curriculum seeks to synthesize and interrelate these concepts into a meaningful cognitive system. The student is not taught management apart from what is managed. He does not learn marketing in one sequence and production in another without careful attention to the dependency relationship between the two functions. He does not learn general concepts in isolated

functional settings so that he is narrowly prepared to understand the operation of a production department, a marketing department, or a finance department. He does not learn quantitative methods as unrelated techniques, nor does he study human behavior in other than an organizational context. Rather, he learns an appreciation of the nature of organizational systems as they are structured internally and as they are related to a larger socio-economic system. He is taught the design, analysis, and coordination of flow systems--not only business systems, but any system that is part of a larger system consisting of human, material, information, and energy resources.

The proposed program replaces the daytime MBA program, which will be discontinued. However, the existing MBA will continue to be offered in the evening. The new program requires a format that is not suited to evening students who have full-time jobs and are pursuing advanced degrees on a part-time basis. For this reason, this proposal for a new program is not accompanied by a request to eliminate an existing program. The College continues to feel an obligation to provide an opportunity for those who wish to update their knowledge of concepts applicable to the management process to do so, whether or not they are free to devote full-time to their studies.

The proposed program is offered as a means of contributing to the preparation of future organizational leadership of a type that will be required in a world of emerging technology, changing societal goals, and evolving human values. The College submits that such a program is required if this geographic region is to avoid having other parts of the world gain a comparative advantage in human resources.

I.

9) Is the proposed program approved by the institution's Board of Control? When?

The proposed degree was approved by the Board of Regents in its meeting of August 5, 1969.

II. PROJECTED ENROLLMENT

II.

10) Project the enrollment for the proposed program for the next five years. Explain the basis for this projection.

Five-Year Projection of Enrollment

1970	1971	1972	1973	1974
30	60	90	120	120

The foregoing estimates of enrollment assume four years would be required for the program to reach its full complement of approximately 120 students. This is believed to be the maximum number that could be handled effectively by our projected graduate faculty while maintaining standards of the highest quality. Enrollment is projected to increase in even increments from an initial contingent of 30 candidates in 1970 to 120 in 1973, at which time it would stabilize. The increments represent a continous cycling of the two-year program with a single wave of 30 students beginning in each of the first two years. In the third year of operation and from then on, if resources permit, two waves of 30 each will be brought into the program in September.

II.

11) Explain the likely source of students who will enroll in this program. (Will they come from existing programs or will they be attracted to the institution to enroll in the proposed program?)

It is estimated that of the thirty students in the initial class of the program, about one-half would come from existing academic programs at the University of Houston and other universities and colleges in the southwest. The remainder of the class is expected to be recruited in roughly equal proportions from schools outside the region and from non-academic organizations in the public, private, and mixed sectors (industry, government, the fine arts, hospitals and clinics, and the like).

III. FACULTY

12) Give the number of persons presently on the faculty who will be most directly involved in the proposed program. List for each his name, rank, highest degree, and present course load.

Department		Name	Highest Degree	Present Course Load
Accounting	1.	Brown, S. H.	M.B.A.	12
	2.	Grinaker, Robert L.	M.B.A.	6
	3.	Hoffman, William H. Jr.	Ph.D.	6
	4.	King, Barry G.	Ph.D.	9
	5.	Lee, Harold O.	Ph.D.	9
	6.	McNeill, I. E.	Ph.D.	6
	7.	Phillips, Lawrence	Ph.D.	9
	8.	Seiler, Robert E.	Ph.D.	6
	9.	Singleton, Roger L.	Ph.D.	3
Behavioral Management Science	10.	Blakeney, Roger N.	Ph.D.	12
	11.	[1]Brannen, T. R.	Ph.D.	3
	12.	Burke, R. L.	Ph.D.	6
	13.	Champagne, J.	Ph.D.	3
	14.	DeMichele, John H.	Ph.D.	3
	15.	Domm, Donald	Ph.D.	9
	16.	Matteson, Michael T.	Ph.D.	9
	17.	Scofield, R. W.	Ph.D.	6
	18.	Sterba, Richard L.	M.A.	9
	19.	Zuckerman, John V.	Ph.D.	3
Business Communications	20.	Stead, Bette	Ph.D.	9
	21.	Wolf, M. P.	Ph.D.	9
Economics	22.	Brown, Bernard	Ph.D.	9
	23.	Daniel, Coldwell	Ph.D.	9
	24.	DeGregori, Thomas	Ph.D.	6
	25.	Dow, Louis	Ph.D.	6
	26.	Mayor, Thomas H.	Ph.D.	9
	27.	Rowe, John W. Jr.	Ph.D.	6
	28.	Sailors, Joel W.	Ph.D.	9
	29.	Shatto, Gloria M.	Ph.D.	9
	30.	Steele, Henry B.	Ph.D.	6
	31.	Stern, Louis H.	Ph.D.	6
	32.	Williams, Earl	Ph.D.	3
	33.	Zahn, Frank	Ph.D.	9
	34.	Zingler, Ervin K.	Ph.D.	6

[1]Dr. Brannen is Dean of the College of Business Administration.

Department		Name	Highest Degree	Present Course Load
Finance	35.	Bolten, Steven E.	Ph.D.	9
	36.	Brosky, John	Ph.D.	6
	37.	Byrd, James A.	Ph.D.	3
	38.	Chen, Henry C.	Ph.D.	Leave of Absence
	39.	Yeager, Francis S.	Ph.D.	9
Marketing	40.	[2]Brien, Richard H.	Ph.D.	3
	41.	Broome, Charles L.	Ph.D.	9
	42.	Cox, Keith K.	Ph.D.	9
	43.	Crane, Edgar	Ph.D.	9
	44.	Enis, Ben	Ph.D.	3
	45.	Kangun, Norman	D.B.A.	9
	46.	Smith, Samuel V.	Ph.D.	3
	47.	Stafford, James E.	Ph.D.	9
Production & Logistics Management	48.	Arcus, Albert L.	Ph.D.	6
	49.	[3]Copen, M.R.	D.B.A.	3
	50.	Daniel, Norman	Ph.D.	9
	51.	Jones, J. Richard	D.B.A.	9
	52.	Ostrofsky, Benjamin	Ph.D.	3
	53.	Rose, Warren	Ph.D.	6
	54.	Ross, H. Glenn	Ph.D.	3
	55.	Triner, Edwin G.	Ph.D.	3
Quantitative Management Science	56.	Brown, James R.	Ph.D.	6
	57.	Crouch, Rolland G.	M.B.A.	6
	58.	Lawless, Robert W.	Ph.D.	6
	59.	Lukas, Andre	Ph.D.	9
	60.	Lumpkin, Irving W.	Ph.D.	12
	61.	Oxspring, Harry H.	Ph.D.	9
	62.	[4]Otto, Gordon	M.S.I.E.	9
	63.	Smith, Lee H.	Ph.D.	3
	64.	Thompson, W. W.	Ph.D.	6

[2]Dr. Brien is Associate Dean of the College of Business Administration.

[3]Dr. Copen is Associate Dean for Graduate Studies of the College of Business Administration.

[4]Mr. Otto's doctoral dissertation is in progress.

13) Calculate the present student-faculty ratio in the subject matter field(s) or department(s) in which the proposed program will be offered. (Divide full-time equivalent students by full-time equivalent faculty.)*

Accounting

Undergraduate 29.0

Graduate 11.2

Behavioral Management Science

Undergraduate 37.3

Graduate 24.0

Finance

Undergraduate 28.3

Graduate 15.8

Marketing

Undergraduate 24.0

Graduate 19.0

Production and Logistics Management

Undergraduate 25.8

Graduate . . . . . --**

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*Calculations based on 1966-67 data and the following definitions:

Undergraduate student FTE's = $\frac{\text{student credit hours taught}}{30}$

Undergraduate faculty FTE's = $\frac{\text{credit hours offered}}{24}$

Graduate student FTE's = $\frac{\text{student credit hours taught}}{24}$

Graduate faculty FTE's = $\frac{\text{credit hours offered}}{18}$

**PLM currently is not an official area of concentration in the MBA program. It will be, however, as of Fall 1969. It also will be a field of concentration in the Ph.D. program.

Quantitative Management Science

Undergraduate 30.4

Graduate 23.6

14) Project the need for new faculty required for the proposed program for the next five years. If the proposed program will be absorbed in part or in whole by the present faculty, explain how this will be done.

Field of Major Concentration	Number of New Faculty Required
Accounting	2
Behavioral Management Science	2
Finance	2
Marketing	1
Production and Logistics Management	2
Quantitative Management Science	1
Total	10

The ten new faculty projected as required over the next five years for the proposed program would not devote their time exclusively to service in the MSA program. A part of their time would be devoted to teaching responsibilities in the Ph.D. and M.B.A. programs, which are expected to continue to expand. Moreover, they will be needed for the daytime masters program, whether it is the MSA or the MBA. One would also serve as program chairman.

The proposed program would be absorbed in large part by the present faculty. Present faculty transferred to the MSA program from the undergraduate program would be replaced by graduate teaching assistants enrolled in the doctoral program and by new faculty assigned to undergraduate teaching. Present faculty transferred from the M.B.A. program would be replaced by new doctoral faculty who would not teach exclusively in the doctoral program and by new terminally qualified faculty assigned to teaching in the B.B.A. and M.B.A. programs.

15) Will acquisition of new faculty required for the program require an unusual outlay of funds or unique recruiting techniques? Explain in detail.

It is not anticipated that the acquisition of new faculty for the proposed program would require an unusual outlay of funds or unique recruiting techniques. Because of its uniqueness, the very presence of the new MSA program would facilitate the recruitment at all levels of the College's educational program.

It would be necessary to recruit most of the MSA faculty at the associate or full professor rank. To obtain the desired quality of new faculty, nine-month salaries in the range of $15,000 to $20,000 would have to be paid. In some cases the figure might run higher.

A related subject is the need for in-house computer facilities which would provide both batch and time-sharing capabilities. Faculty members who have the desired qualifications are invariably concerned with easy access to such computer systems, and often specify their availability as a prerequisite to accepting a position. The College recently installed an IBM 1130 system. (See section 21).

16) Describe the involvement of the faculty, present and projected, in research, extension, correspondence, and other activities. Are teaching loads of faculty reduced if they engage in these activities?

All graduate faculty are expected to engage in individual research activity as a part of their normal academic load. Where the research activity becomes intense, as in the case of research conducted under grant or contract, or in the case of unfunded research which shows immediate promise of resulting in publishable scholarly articles or monographs, the faculty member is granted released time from teaching and other duties.

In view of the lack of comparable programs elsewhere in the country, the MSA faculty will be heavily involved with curriculum development during the first two years. An integral part of this activity will be the development of teaching materials for use in the program since such materials presently are non-existent. It is therefore anticipated that some released time may have to be provided during the pioneering stages.

The members of the faculty of the College of Business Administration do not participate in educational programs involving extension or correspondence classes. Some members do participate in the programs of the Management Development Center of the College. No reduction in teaching Load has been provided for these limited activites.

The faculty is encouraged to engage in consulting when such activity involves conceptual thinking and the solution of original and difficult business problems or when the activity may result in scholarly publication. The faculty member may devote no more than an average of one day per week in such activity.

The growing interest and competence of the College's faculty in the area of research and publishing is indicated in the following data:

PERIOD	ANNUAL PRODUCTION OF BOOKS	ANNUAL PRODUCTION OF ARTICLES IN MAJOR PUBLICATIONS	ANNUAL PRODUCTION OF OTHER PUBLICATIONS
April '63 - March '65	1	8	2
April '65 - March '67	4	19	7
September '67 - June '68	21	73	39

IV. Library

The following table indicates the present status of library holdings by field of concentration with respect to academic journals, research monographs, business journals and periodicals, classic works, corporate reports, federal and state governmental documents and foreign titles and governmental publications.

PRESENT STATUS OF LIBRARY HOLDINGS IN SELECTED AREAS

Field of Concentration	Rating			
	Excellent	Good	Fair	Poor
		Academic Journals		
Accounting			X	
Behavioral Management Science	X			
Finance		X		
Marketing		X		
Production and Logistics Management		X		
Quantitative Management Science		X		
		Research Monographs (University Bureaus of Business Research)		
Acc		X		
BMS		X		
Fin		X		
Mkt		X		
PLM		X		
QMS		X		

Field of Concentration	Rating: Excellent	Good	Fair	Poor
Business Journals and Periodicals				
Acc			X	
BMS	X			
Fin	X			
Mkt	X			
PLM		X		
QMS		X		
Classic Works				
Acc			X	
BMS		X		
Fin				X
Mkt		X		
PLM		X		
QMS			X	
Financial and Related Corporate Reports				
Acc		X		
BMS		N.A.		
Fin		X		
Mkt		N.A.		
PLM		X		
QMS		X		
Federal Governmental Documents				
Acc		X		
BMS		X		
Fin				X
Mkt				X
PLM			X	
QMS		X		
State and Local Governmental Publications				
Acc		X		
BMS		N.A.		
Fin	X			
Mkt			X	
PLM				X
QMS		X		

Field of Concentration	Rating			
	Excellent	Good	Fair	Poor
	Foreign Titles and Governmental Publications			
Acc				X
BMS				X
Fin				X
Mkt				X
PLM				X
QMS				X

j. Are there libraries of other institutions which are being used or could be used by faculty and students in the proposed program? Explain in detail.

Fondren Library -- Rice University
Houston Public Library
St. Thomas University Library
Texas Medical Center Library
Texas Southern University Library
U. S. Department of Commerce Regional Library
World Trade Center Library

The Fondren Library at Rice University is a long-established and excellent university library that has been developed to support research programs in many fields, including economics, mathematics and psychology. Rice has plans for the development of a graduate program in business and should be adding heavily to their collection in this area during the next several years. The Houston Public Library is a public depository containing many governmental documents of older vintage that would be available for student use. The shelves of the U. S. Department of Commerce Regional Library contain much data helpful to students in the field of marketing. The Bureau of International Commerce section of this library and the World Trade Center Library contain many items useful to students interested in the international aspects of business. The excellent Texas Medical Center Library is a good source for materials in the field of medical and hospital administration.

17) Are present library holdings in relevant fields adequate now to begin the proposed program? How will the library have to be improved to meet program needs in the next four years? (Refer to the need for books, periodicals, reference books, primary source materials, etc.)

Areas of excellent library support are now available in some fields with respect to academic journals and state and local governmental publications. The Center for Research in Business and Economics has a good selection of research monographs published by the member schools of the American Association of University Bureaus of Business Research that are readily accessible to graduate students. Also most fields of concentration report good or adequate library support with respect to classic works, corporate reports, and federal, state and local governmental documents. Foreign titles and governmental publications, however, are areas of critical inadequacy and much hard work and considerable time will be required to bring these holdings to an acceptable level of adequacy. Supplementation of existing holdings will additionally be needed in the area of academic and business journals and periodicals (accounting), classic works (accounting and finance), federal governmental documents (finance, marketing and production and logistics management), and state and local governmental documents (marketing and production and logistics management). The fact that the University of Houston Library is a public depository will help greatly in eliminating deficiencies in the area of public documents.

19) Estimate the total expenditures for the last two complete fiscal years for library acquisitions in the departments or subject matter fields in which the proposed program will be offered, or in fields which are closely related to the proposed program.

20) Project library expenditures to be budgeted annually for the next five years to meet the need of this program.

Department	Total Library Budget 1967-69	Additional Expenditures for Current Acquisitions for MSA Program 1969-70	1970-71	1971-72	1972-73	1973-74	1969-74
Accounting	$ 2,000	$ 200	$ 200	$ 300	$ 300	$ 400	$1,400
Finance (excluding Economics)*	2,500	200	200	300	300	400	1,400
General Business	1,000						
Quantitative Management Science	2,000	200	200	300	300	400	1,400
Behavioral Management Science	1,750	200	200	300	300	400	1,400
Marketing	2,000	200	200	300	300	400	1,400
Production and Logistics Management	1,700	200	200	300	300	400	1,400
All Departments	$12,950	$1,200	$1,200	$1,800	$1,800	$2,400	$8,400

*Excludes $9,000 allocated to Economics.

It is anticipated that this program will require only insignificant additions of new titles to the holdings of existing departments in view of the increased acquisitions required by the existing programs and those already estimated for the Ph.D. Primary increases will come from the need for multiple copies of some books to service the additional students. However, it is possible that the MSA will generate demands in other non-business fields for students who are taking elective programs which deal with administration in non-business sectors.

V. FACILITIES AND EQUIPMENT

21) Describe existing facilities that are available for the proposed program. Describe the present utilization of these facilities. What new facilities will be needed in the near future? Specify what special facilities and equipment will be needed and estimate their cost. From what sources do you anticipate obtaining needed facilities and equipment.

The College of Business Administration is presently housed in the Fred J. Heyne Building. This building, completed in 1958, was a gift of the Houston Endowment Fund, Inc. In addition to 85 offices and 30 classrooms, this centrally air-conditioned building houses in special facilities the Management Development Center and the Center for Research in Business and Economics.

Office space in the building is presently fully utilized. However, current plans call for the allocation of over 30,000 square feet of office and classroom space in the proposed Graduate Studies Building to meet the needs of the graduate division of the College of Business Administration.

Future plans call for the construction of a tower addition to the building, if needed, primarily to accommodate any further expansion of the College of Business Administration.

The only major additional facility required is a computer network containing batch processing and time-sharing capability. However, this is not a unique requirement of the MSA program as it is urgently needed for all other degree programs in the College. But the availability of such facilities are virtually mandatory for the implementation of the MSA. The cost of such equipment will be of the order of magnitude of $50,000/year, but the incremental cost

for the MSA program will be insignificant as most of the expense will be absorbed by regular budget commitments for all programs. The College has taken delivery on an IBM 1130 system which will meet our initial needs, but which will have to be upgraded subsequently to handle the instructional and research requirements of all of the College's programs.

VI. Administration of Proposed Program

22) Will the proposed program affect the administrative structure of the institution? If yes, describe how. In what department, division, school or college will the proposed program be administered? If the program is to have inter-departmental or inter-unit administration explain in detail.

The proposed program would affect the administrative structure of the institution only in that the MSA would be administered as a program. The program director would sit on the Administrative Committee, the major policy board of the College.

The program would be administered in the College of Business, by Dr. Ted R. Brannen, Dean. The direct supervision and coordination of the program would be the responsibility of the Director of Graduate Studies in Business, working in cooperation with the appropriate committees and the program chairman. All admissions to the program would be cleared through an inter-departmental Admissions Committee, and each candidate would be assigned an inter-departmental Graduate Advisory Committee. The faculty assigned to duties in the program would be members of the University and the College Graduate Faculties. Program development would be under the guidance of the Graduate Faculty of the College of Business Administration whose recommendations would be carried to the Dean of the College, and other appropriate University officials and external bodies, when required, for final approval.

VII. Accreditation

23) Describe the requirements for accreditation, if program is eligible to be accredited. What is the name of the accrediting agency? What will be initial costs of accreditation and subsequent annual costs to maintain it? Identify basic criteria for accreditation and describe how these will be met.

The American Association of Collegiate Schools of Business (AACSB) has been designated by the National Commission on Accreditation as the official agency for program accreditation in the field of business administration. The AACSB accredits Bachelor and Master of Business Administration degree programs.

The Bachelor of Business Administration degree program at the University of Houston received AACSB accreditation in 1964. The Master of Business Administration degree program at the University of Houston received AACSB accreditation in 1967, the seventy-seventh M.B.A. program accreditation conferred in the U. S. by the AACSB -- and the fifth in Texas. Since the College of Business has already been accredited at the master's level and the proposed M.S.A is precisely in keeping with the academic philosophy expressed in the official publications and curriculum development guidelines of the AACSB, we anticipate that accreditation will be automatic, requiring only that we file a record of the new program with the AACSB.

VIII. Supporting Fields

24) Evaluate the subject matter fields at your institution which may be considered as necessary, or valuable, in support of the proposed program. Will these fields need improvement? If so, how, to what extent, and at what cost? Be specific.

The subject matter fields most necessary and valuable in support of the proposed program are economics, psychology, sociology, law, political science, and the fine arts. It is anticipated that most non-business electives will be taken in these fields, all of which are sufficiently strong to provide, with proper counsel and cooperation, excellent non-business elective sequences for the MSA candidates.

IX. COST OF PROPOSED PROGRAMS

25) Estimate the initial (first year) costs of the proposed program. How much of this will be absorbed in current budgets and how much will be newly appropriated money? Will federal or private financial assistance be sought? If yes, explain in detail.

The estimated first-year cost of the proposed program, based on the net addition of four FTE faculty members, including a director for the program, is about $104,000. An item break-down of this total figure is shown below:

First-Year Costs[1]

Item	Estimated Cost
Faculty (4 FTE)	[illegible][2]
Secretary	[illegible]
Travel	2,500
Operating expense	1,200
Office equipment	[illegible]
Total	$104,033

It should be emphasized that to a great degree these are replacement costs rather than incremental costs; that is, they represent the cost of a growing daytime masters program, whether it is designated MBA or MSA. It is hoped that these costs could be included in the new budget allocated to the College from the University's state funds; however, funds are being sought also from both federal and private sources. Federal financial assistance is being requested under one of the Higher Education Admendments of 1968, as passed by the 90th Congress. If obtained, these funds will be applied to the development of the entire program; a proposal has also been submitted to NASA for financial assistance in developing selected areas of the program.

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[1]Library costs and graduate teaching assistantship costs are shown respectively, under Section IV, Library, 20), and Section IX, Costs of Proposed Program, 29).

[2]Includes allowance for half-time summer pay for eight faculty members in summer 1970, to develop course structures and prepare teaching materials.

In addition, private funds for graduate fellowships, travel and research will be sought with the assistance of the Office of University Development, the recently organized Advisory Council for the College of Business Administration, and the College of Business Administration Alumni Association. The Business Advisory Council consists of fifteen of the top business leaders of Houston. This body is currently organizing a fund raising program in behalf of the College.

26) Estimate the annual cost of the program for the three years following its first year, using current formulas. Explain the rationale of your estimate.

Projected Annual Cost of the Proposed Program

1971	1972	1973
$113,000	$170,000	$226,000

The foregoing projected annual costs of the proposed program are based on projected enrollments of 60, 90, and 120 (student head-count) for the 1971, 1972, and 1973 academic years. (See II. Projected Enrollment). The head-count enrollments were multiplied by a course load factor of 15 and by a semester factor of 2. The total semester hours taken each year were then multiplied by $62.97 to arrive at an estimate of annual program costs. The figure of $62.97 represents the total of the teaching salaries ($47.25), departmental operating ($11.58), and library ($4.14) formulas projected for the 1971 fiscal year by the Coordinating Board.

27) Departmental Costs.

(A) Show the departmental operating expenditueres for the last two fiscal years for the departments which will contribute significantly to the support of the proposed program.

All departments in the College will be actively involved in the new program. The following tables reflect the old organization structure

and nomenclature of the College. The current departments include Accounting, Behavioral Management Science, Economics, Finance, General Business Administration, Marketing, Production-Logistics Management, and Quantitative Management Science.

APPROPRIATED BUDGET 1967-68

COLLEGE OF BUSINESS ADMINISTRATION

Department	Professional Salaries	Clerical Salaries	Travel	Maintenance and Operation	Equipment	Total
Accounting	$ 228,105	$10,620	$ 1,100	$1,200	$ 910	$ 242,935
Economics and Finance	347,650	15,275	1,760	2,550	2,305	369,540
General Business	269,400	12,275	1,500	2,680	3,910	289,765
Management	102,775	4,810	800	940	2,690	112,015
Marketing and Advertising	131,670	6,750	800	1,080	190	140,490
Transportation and International Business	63,900	4,710	400	600	-	69,610
Summer Teaching Salaries	180,000					180,000
Totals						
Teaching Salaries	$1,323,500					$1,323,500
Departmental Operating Expenses		$53,440	$10,050	$6,360	$10,005	79,855
Administration	31,800	20,460	2,200	2,115	4,985	61,560
	$1,355,300	$73,900	$12,250	$8,475	$14,990	$1,464,915

APPROPRIATED BUDGET 1968-69

COLLEGE OF BUSINESS ADMINISTRATION

	Professional Salaries	Clerical Salaries	Travel	Maintenance and Operation	Equipment	Total
Accounting	$ 231,120	$ 15,480	$ 1,100	$ 2,200	$ 910	$ 250,81
Economics	251,185	14,185	1,160	1,950	2,050	270,53
Finance	102,740	4,890	600	600	255	109,08
General Business-Quantitative	196,160	7,510	1,000	1,625	3,500	209,79
General Business-Non-Quantitative	141,795	5,065	500	1,055	405	148,82
Management	142,510	5,050	800	940	2,690	151,99
Marketing and Advertising	144,190	7,050	800	1,080	190	153,31
Production and Logistics Management	74,090	4,890	400	600		79,98
Unallocated				5,000		5,00
Summer faculty salaries	193,910					193,91
Totals						$1,477,70
Teaching salaries	$1,477,700	$ 64,120	$ 6,360	$ 15,050	$ 10,000	95,53
Departmental operating expense		20,940	2,115	2,200	4,985	76,57
Dean's office	46,335					
	$1,524,035	$ 85,060	$ 8,475	$ 17,250	$ 14,985	$1,649,80

(B) How will the proposed program affect the allocation or distribution of these funds?

On balance, the new program is expected to cause no significant shifts in the pattern of distribution of the College's funds among its departments.

28) What additional funds for research will be needed to support the proposed programs? Explain.

Funds for research to support the proposed program are essential. They will provide for continuous program enrichment and the attraction of outstanding students to the program. Such funds could be used:

1) To provide additional released time for faculty to engage in research, either on an individual or group basis. Such supported research efforts would enrich the quality of graduate teaching, enhance the reputation of the faculty and the College, provide expanded research experience, and generally create the excitement of a vigorous research environment so vital to graduate programs of instruction.

2) To provide support for graduate research assistants who would assist the faculty in individual or group research activity.

A major research program is being initiated in the fall of 1969 through a sub-branch of the Center for Research in Business and Economics. It involves studies of organizational behavior in management systems with particular attention to computer-based decision-information systems. This program will provide crucial support for the M.S.A. degree program. For example, NASA/MSC has expressed interest in supporting the program of research and the concomitant development of a series of elective courses in the M.S.A. in Science and Technology Management.

29) How many assistantships are considered desirable to begin the program? Estimate the amount of funds required for these assistantships over the next four years. What sources are available to support these assistantships? Explain in detail.

The most desirable pattern of cumulative total assistantships is indicated below. A reduced number of assistantships would not preclude the success of the program.

GRADUATE ASSISTANTSHIPS NEEDED
FOR THE PROPOSED PROGRAM

	Year			
	1970	1971	1972	1973
Number	20	30	45	60
Cost	$60,000	$90,000	$157,500	$210,000

The nine-month stipend is assumed to be $3,000 during 1970 and 1971, rising to $3,500 in 1972 and 1973. The figures for the last two years would be diminished by approximately one-half if a decision is made to enroll only one wave of 30 students each September, rather than two beginning in 1972. These assistantships would be financed principally out of non-state funds; that is, from organizations and foundations interested in supporting the supply of the kind of sophisticated management talent the program seeks to provide to all sorts of complex organization in virtually all sectors of society.

30) Add any comments which would be helpful to the Coordinating Board in evaluating this program request.

ATTACHMENT B

CEMSA

Center

for

Management Studies and Analyses

(CEMSA)

in the

College of Business Administration

University of Houston

October 1969

THE CENTER FOR MANAGEMENT STUDIES AND ANALYSES (CEMSA)

I. GENERAL DESCRIPTION OF CEMSA

Role and Scope

With its part time administrative staff initially being obtained from the faculty of the College of Business Administration of the University of Houston, CEMSA will be a financially self-supporting contract research center. It will address itself on a project basis to the many problems in management information science and management systems that currently confront virtually all complex organizations in both the private and public sectors of our economy. While individual projects may be essentially proprietary, CEMSA will have an overriding, long-term purpose of abstracting significant aspects of each study and synthesizing them into a general body of knowledge in the management system. Section II of this proposal discusses the rationale and objectives of CEMSA in greater detail.

Legal Organization

It is proposed that the Center for Management Studies and Analyses (CEMSA) be an integral portion of the College of Business Administration with an Advisory Board comprising both top managers from Houston-area business, industry and government and members of the administration and faculty of the University of Houston.

Administrative Structure and Staff

The Center will have as its administrative nucleus a small part time staff, comprising at the outset a Director and one secretary. Should the growth of the Center justify requirements for full time administrative staff, qualified applicants will be sought. This initial staff will grow as necessary as the work of the Center develops, and will be complemented at any given point in time by as many part-time/ and or temporary investigators as are required to execute the projects under contract. These investigators will be drawn from the following sources: the University of Houston faculty, the University of Houston graduate student body, special consultants not available from within the University, and the client organization(s) for the project. Industry and government investigators generally will be relieved of their normal duties in their organizations and will be assigned full-time to the Center for the contracted life of their project. Others may be drawn in for short-term assignments within the life span of a given project. Project direction will be vested in CEMSA.

Funding

It is estimated that the demand for the kind of research projects CEMSA will undertake is great enough in the immediate area alone to put the Center on a self-financing basis from its inception.

II. RATIONALE AND OBJECTIVES OF CEMSA

The Need for Research in the Management Sciences

A decade ago, it was observed by a management information specialist that "half the cost of running our economy is the cost of information. No other field offers such concentrated room for improvement as does information analyses".[1] Since that observation was made, the world's accumulation of knowledge has allegedly doubled, and it will at least double again in the next decade.

American business, as well as organizations in the public sector, are caught in an ironic dilemma: our economic system generates a massive volume of data daily, and the rate of information-generation is increasing, yet most managers continue to complain that they have insufficient, inappropriate, or untimely information on which to base operating decisions.

The chances of getting out of this dilemma appear to rest heavily on two major, related developments in the management of business organizations: the application of systems theory and the advent of the computer. The systems concept has roots in the natural and physical sciences and in engineering, but its applications to human decision-making probably originated in the development of optimal attack and defense patterns during World War II. In its military context, the systems approach was defined by the RAND corporation in a fashion which seems equally appropriate for business strategists:

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[1]Adrian McDonough, "Today's Office-Room for Improvement," Dun's Review and Modern Industry (September, 1958), p. 50.

> An inquiry to aid a decision-maker in choosing a course of action by systematically investigating his objectives, comparing quantitatively where possible the costs, effectiveness, and risks associated with the alternative policies or strategies for achieving them, and formulating additional alternatives if those examined are found wanting.[2]

The systematic analyses of costs, risks and outcomes require that huge amounts of data be generated, processed and acted upon extremely rapidly, so the computer has become an integral part of most management information systems. Its tremendous capacity for data storage with micro-second retrieval, dissemination, and analyses, as well as its great cost, have caused many organizations to plan formally for the first time their management information flows and processing functions.

It is anticipated that CEMSA will address itself to a wide variety of research projects ranging from highly technical matters such as special programming, model building, and simulation to analyses of the organizational behavior implications of man-machine systems. The latter area may be of special interest to CEMSA since many computer equipment suppliers, systems analysts, and line managers agree that computer-based systems often are not installed where they might well be of great benefit, or, if installed, are underused or ineffectually applied, simply because the human organization is insufficiently systematized to capitalize on the machines' capabilities.

Discipline Synthesis

The "information explosion" of recent years will test as never before the ability of the organization to integrate men, machines, and

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[2]Lee Adler, "Systems Approach to Marketing," Harvard Business Review (May-June, 1967), p. 112.

procedures into an effective management system. As one concerned top manager, this one in the military expressed it:

> Information, including management information, is growing by the micro-second and even the nanosecond. We cannot turn off the flow. We had therefore better learn to control it--and we are already running late.[3]

The kinds of projects CEMSA will undertake will almost certainly require an interdisciplinary approach. For example, an attempt currently underway to build just the marketing sub-system of an overall management information system in a consumer packaged goods company in the Houston area involves top management, marketing management, brand management, sales management, new products groups, the marketing research staff, the control and finance departments, production scheduling, delivery scheduling, the advertising agency, systems analysts and designers, operations researchers, statisticians, programmers, and computer equipment suppliers.

It is clear that the complex nature of most current operational problems necessitates the integration of the diverse skills and knowledges related to all the variables which may impact the problem. The recent achievement of placing a man on the moon is as much or more a tribute to the management of discipline synthesis than to technological and scientific advancements of hardware. Discipline synthesis has recently been recognized as an urgently needed discipline within the management sciences. The application of the science of discipline synthesis to

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[3]Howell M. Estes, "Will Managers Be Overwhelmed by the Information Explosion?", Armed Forces Management (December, 1966), p. 84.

operational problems and the advancement of this science resulting from the experiences gained in the application provide the theory to application to theory feedback loop which is at the heart of CEMSA's raison d'^etre.

The Unique Advantages of the Center

A university-based, project supported Center for Management Studies and Analyses has a number of meaningful advantages. By drawing its project teams from the University's faculty and graduate students and by including full-time, although temporary, participants from industry and government, such an organization can probably concentrate more interdisciplinary talent and develop a better mix of theoretical and operational perspectives on a given project than could either a strictly commercial or an exclusively academic research body.

By attracting industry and government participants into the project on a full-time basis, that is, by having such investigators orient almost exclusively to the Center during the life of their project, CEMSA will provide the kind of shelter from routine operations or "brush-fire-fighting" that an investigator needs to do a first-rate piece of research.

By focusing upon operational problems within industry and government, both faculty and students will be afforded the opportunity to test theoretical concepts in a "real-world" laboratory. At the same time, industry and government will obtain the benefits of applying the latest theoretical knowledge to their complex problems.

The Objective of CEMSA

CEMSA may be considered to have three objectives, one for each of its two principal constituencies and a superordinate objective for the Center itself.

1. For its client organizations, CEMSA will provide a project task force of precisely the size and composition necessary to solve specific problems in the field of management science.
2. For the College of Business Administration, and quite possibly for other colleges or departments within the University, CEMSA will represent on-going, major research out of which will come enriched curricula, student theses and dissertations and significant faculty publications.
3. For the Center itself, the primary objective will be to make major contributions to the body of knowledge in management science. Through continuing comparative analysis of the problems, treatments, determinants, and outcomes of the Center's projects, CEMSA will work toward synthesizing a theory of management science.

ATTACHMENT C

PERSONAL DATA SHEETS

ALBERT L. ARCUS

Basic data

Aged 46, single, excellent health, height 6'-0½", weight 195 lbs., U.S. citizen (formerly Australian), top secret security clearance.

Academic data

B.E. University of Western Australia 1945 (civil engineering).
M.A. University of Oxford, U.K., 1952 (economics and politics).
Ph.D. University of California, Berkeley, 1963 (business administration - operations research, accounting, economics).
Awarded a Rhodes Scholarship 1946.
Awarded a Ford Foundation Pre-doctoral Fellowship 1958 and 1959.
By examination, licentiate of the Chartered Institute of Secretaries (i.e. of Canadian corporations) 1959.
All education prior to 1945 was in Western Australia where born.

Employment data

1966-68 Senior Research Associate, Logistics Management Institute, Washington D.C.. Applied research into logistics problems solely for the Dept. of Defense. High-level projects concerned the supply systems of all military services.

1964-66 Lecturer, Production Management Division, Graduate School of Business Administration, University of California, Los Angeles. Full-time teaching of production management courses at graduate and undergraduate levels (BA142, 144, 242) and in the 1966 Engineering and Management Course for industry.

Mid-64 Supervisor, Charitable Trusts Project, Dept. of Justice, California. Programming, collation and analysis of data concerning 7,000 charitable trusts.

1963-64 Professional Counselor, International Labor Office, Geneva. Assigned to India to assist in the creation of colleges of industrial management and earth-moving projects.

1962-63 While completing a doctoral dissertation at the Graduate School of Business Administration, University of California, Berkeley, also lectured in production management (BA140, 142) there full-time. Was also a teaching assistant in accounting 1957-58.

1959-62 Senior Consultant, Management Sciences Division, Touche Ross Bailey and Smart, New York. Advised clients on a wide range of business and technical problems; e.g. Sears Roebuck on factoring accounts receivable, Mead Corp. on taxation of subsidiaries, Fenestra Corp. on scheduling extrusions, Bucyrus-Erie on smoothing production, Hudson Bay Stores on buying seasonal goods, Allstate Insurance on creating an operations research group, and so on. A technique developed for balancing the assembly lines of Chrysler Corp. is probably the most advanced anywhere. Also wrote the "Preliminary report on the unification of accounts of the government of the state of Hawaii", with others participating, for the Legislature of Hawaii.

1957-59 Doctoral studies at the University of California, Berkeley.

1955-57 Contracts officer, Department of Defence Production, Ottawa, Canada. Wrote and administered aircraft contracts, supervised capital assistance programs, audited financial and production reports.

Mid-55 Director and Secretary, Arcus Metal Products Pty. Ltd., Perth, Australia. Reorganized this family company during a period of crisis. It manufacturers domestic and commercial refrigerators, hot water systems and the like.

1952-55 Assistant Trade Commissioner, Dept. of Commerce and Agriculture, Canberra, Australia. Assigned to the Australian Embassies in Indonesia and Japan. Acting Commercial Counselor about 70% of the time. Work involved trade promotion, market surveys and all kinds of investigations on behalf of government and industry. High-level representations initiated large exports of Australian coal to Japan.

Prior to 1952 employment included about 5½ years of miscellaneous structural design and construction, time study and methods engineering, production planning and control, operation of gas, acid and smelting plants, and company law studies. Service in the Australian Army during World War II amounted to 1½ years, ending as Lieutenant in the engineer corps.

Publications

"COMSOAL: A Computer Method of Sequencing Operations for Assembly Lines, I - The Problem in Simple Form, II - The Problem in Complex Form", in Readings in Production and Operations Management (ed. E.S. Buffa) John Wiley & Sons, Inc., N.Y., 1966. Also published in slightly different form as "COMSOAL: A Computer Method of Sequencing Operations for Assembly Lines", International Journal of Production Research, Vol. 4, No. 4, 1966.

Associations

Sometime member of:

American Accounting Association
The Institute of Management Sciences
Operations Research Society of America
(Chairman of the Finance Committee, National Meeting, 1960)
American Institute of Industrial Engineers
Chartered Institute of Secretaries
American Production and Inventory Control Society
Beta Alpha Psi
Sigma Gamma Delta
Mensa

RESUME OF BENJAMIN OSTROFSKY

November - 1968

Home Address: 3668 Meadville Drive
Sherman Oaks, California
91403

Phone: (213) 788-7133

Birthday: 26 July 1925
Place: Philadelphia, Pennsylvania

Married, two children - son-age 6, daughter-age 9

FORMAL EDUCATION:

- Central High School, Philadelphia, Penna., 1942
- BSME with Option in Aeronautical Engineering
- Drexel Institute of Technology, December 1947

- Master of Engineering, UCLA, June 1962
  (Engineering Executive Program)

- Ph.D. in Engineering from UCLA with Major Field of Engineering Design and Minor Fields in Applied Math and Engineering Management, March 1968

PROFESSIONAL SOCIETIES

American Society for Engineering Education
Operations Research Society of America
American Institute of Aeronautics and Astronautics,
American Association for the Advancement of Science

Honors: Sigma Xi
Blue Key Society, Drexel Institute of Technology

RECENT IMPORTANT ACTIVITIES

1962 to 1965: Ford Foundation Educational Development Program Assisted in development of undergraduate design curriculum and taught lower division design courses, UCLA. Read upper division and graduate courses.

1965 to present: Taught Engineering System Design, UCLA.

Summer, 1965: Lectured in NSF Design workshop for four weeks at UCLA in Design Morphology to guest Faculty and Students and attended summary session at Carnegie Institute of Technology.

Summer 1964
Winter 1966
Winter 1967
Winter 1968

Lectured in short courses to industry on Engineering Design Theory.

MILITARY EXPERIENCE (5 Years)

October 1943 - October 1945

Aviation Cadets, Army Air Corps; Graduated as a navigator-bombardier, December 1944.

September 1950 to October 1953

- Radar-bombardier-navigator on B-45 aircraft in tactical operations
- Group navigator in a Troop Carrier Wing
- Plans and Requirements Officer in an Observer Training Group

Two years in the Alaskan Air Command as a navigator on C-54 and C-124 aircraft; including additional duty as a squadron adjutant.

Flying duty in the Alaskan Air Command included participation in the development of Polar Navigation techniques as well as initial reconnaissance for the DEW line. Resupply missions were also accomplished at T-3 Ice-Island (89 degrees north latitude).

Total flying time at separation was approximately 2000 hours of which approximately 1300 hours was in the arctic.

PROFESSIONAL ACTIVITIES

1964 - Present:

Senior Staff Engineer at TRW Systems, Redondo Beach, California. Advisor and consultant to manager of logistics laboratory for advanced weapon and space systems design and operational problems.

Served as Ad Hoc advisor to USAF for two years to develop audio-visual aids for improving efficiency of maintenance of advanced technological systems.

Served as consultant to USAF for devising a computerized system of employing flight test information to improve accuracy of forecasting operational requirements for the F-111A aircraft. (and others).

1961 - 1964

Member of the Technical Staff, TRW Systems, Systems Research Laboratory. I was responsible for conceptual and analytical studies of Military Weapon Systems and Space Systems. These studies involved current systems as well as those being proposed, and reflected considerations of the system as an entity.

One of the major efforts was the determination of a method to measure alert readiness for the Atlas Weapon System, and an application of this method using actual data from missile sites. The results of this study are influential in determining USAF policy for operating and maintaining Atlas missile sites.

November 1954 to May 1957 (2 1/2 years)

Douglas Aircraft Company
Testing Division

Title: Research Test Engineer

Conducted a research test program at Edwards AFB to compare and evaluate two types of equipment used to measure gun gas concentrations (see publication) This problem involved the supervisory control of an A4D-1 aircraft, two shifts of maintenance personnel, and an intensive instrumentation program.

Following this test program, responsibility was assumed for all propulsion and mechanical system flight test programs on the A3D Aircraft. The complete planning, instrumentation, flight tests, data reduction, reporting and liaison functions were included in this responsibility. Instrumentation was accomplished at the El Segundo location, flight testing at Edwards AFB, data reduction and reporting at the Santa Monica location.

November 1953 to November 1954 (1 year)

Generator Equipment Company, Los Angeles

Title: Chief Engineer and Production Manager

Designed and produced auxiliary ground power equipment on sub-contracts for the USAF. Assisted the company president in managing the production facility and personnel (approximately 60 people). Developed administrative and shop procedures for the production line to increase output during this period.

October 1948 to September 1950 (2 years)

George C. Lewis Company, Consultants
Philadelphia, Pennsylvania

Title: Project Engineer

Designed, directed the procurement, supervised installation and testings, and coordinated all phases of the projects assigned for major commercial air conditioning and structural projects.

February 1948 to August 1948 (1/2 year)

E. G. Budd Manufacturing Company
Red Lion, Pennsylvania

Title: Production Test Engineer

Conducted production line testing of mechanical and electrical equipment aboard new railroad coaches.

PAPERS AND REPORTS - a partial listing

B. Ostrofsky, N. S. DuBois, T. S. Arnold, "System Effectiveness Data System" (SEDS); Report No. SAMSO-TR68-131, Space and Missile Systems Organization Report, USAF, March 1968

B. Ostrofsky, N. C. Pate, N. S. DuBois, "System Experience Correlation and Analysis Program", Report No. SAMSO-TR67-12 Space and Missile Systems Organization Report, USAF, August 31, 1967

"Design of An Experiment For the Inferential Evaluation of Statistical Errors in Weapon System Capability Assessment" (Term Paper) UCLA, Fall, 1962

"Feasibility of Weapon System Automated Maintenance" (Part of Field Examination in Design), UCLA, Spring, 1963

"Future Basic Requirements for Systems Data In USAF", USAF/Industry Data Management Symposium, Spetember 1965, Los Angeles, California

"Alert Readiness For A Missile Weapon System" STL Report (now TRW) No. 6301-6129-OS-000 (Secret), 9th meeting of the Military Operations Research Society, Fort Monroe, Virginia (co-authored with R. E. Wesel, and P. D. Chaiken)

"A Methodology For The Preliminary Comparison of Lunar Landing Vehicle Configurations", Institute of Aeronautical Sciences (now AIAA), Annual Summer Meeting, Los Angeles, California, June 19-22, 1962

"A Current Survey Of The Probability Of Catastrophic Failure in Minuteman Silo Operations", STL Report No. 9863-601, 18 October 1961

"A Priori Determination Of The Number Of Missiles For Verification of CEP Requirements For A Given Level of Significance and Efficiency of Ground Operations", STL Report No. 9863-548, September 28, 1961

"Feasibility Of Standardizing SM-62 Trajectory Planning", Report No. NOR-60-105, Norair Division, Northrop Corporation, June 1960

"SM-62 Mission Planning Guide" Report No. NOR-59-149, Revision B, Norair Division, Northrop Corporation

"A Preliminary Evaluation of N-156F Maintainability" Report No. NAI-58-601, Norair Division, Northrop Corporation, January 1958

"A Comparison of Brenco Gun Gas Detector with Bottle Sampling Technique In Flight", Douglas Aircraft Co., Sept, 1955

DISSERTATION

"Theory For Criterion Function Synthesis In Design" UCLA, March 1968

"On the Determination of Group Relative Values for Maintenance Criteria" - presented at Third Annual Convention "Society of Logistics Engineers" Los Angeles, California, Sept 5, 1968.

"System Design Criteria as Probabilities" - presented to National Meeting of ORSA. Philadelphia, November 7, 1968.

VITA

EDWIN G. TRINER
15427 Baybrook Drive
Houston, Texas 77058

Tel. 488-5650

Married 2 children 5 feet 11 1/2 185 pounds Health good

1969-Present

. Director, Center for Management Studies and Analyses, . . . Chairman of the Department of Production and Logistics Management... Special Assistant to the Dean of the College of Business Administration for Advanced Planning.

1967-1969

. Managing Scientist at Serendipity Associates responsible for Program Management. Prepared program plan, developed organizational structure and established resource allocation priorities for the Fire Research and Safety Center of the National Bureau of Standards . . . As consultant to the Director of the Institute for Applied Technology of the National Bureau of Standards, furnished a study plan for and a briefing outline of the NBS project to investigate the development of the performance concept for low cost housing. Assisted in the development of the study strategy and of the structure of the final report to HUD . . . Planned and conducted a course of instruction for the Building Research Division of the National Bureau of Standards in the principles and methods of functional oral presentations. Course was conducted by a combination of lecture, seminar and practicuum. . . Performed a classified analytical study for the Joint Chiefs of Staff . . . Conducted training session of the Chief for Research of the Bureau of Medicine and Surgery, U.S. Navy and his staff on the applicability of Planning, Programming and Budgeting concepts to the Bureau's research program requirements . . . Critiqued for the Army Materiel Command the status of the development of a system/equipment/part identification and control numbering plan . . . Consultant to the Army Materiel Command technical director for the development and installation of a Technical Data Center . . . Developed for Bell Telephone Laboratories the procedures for determining during the acquisition of a computer based information system the qualitative and quantitative personnel requirements for the new system.

1966-1967

. Staff Assistant to the Assistant Secretary of Defense for Systems Analysis. Developed Manpower Cost Model for man/machine investment trade-offs being used on three major weapons systems . . . Wrote Department of Defense (DoD) Directive on Manpower Resource Requirements in System Design, Development, Operations and Logistic Support Planning . . . Assisted in development of Air Force Pilot Inventory Model employed in the defense force structure analysis. Planned and initiated the formation of a DoD Military Manpower Cost Study Group whose function is to develop a manpower investment cost model

to be employed in man/machine investment trade-offs . . . Introduced capital/labor investment trade-off requirements during concept formulation and contract definition in Navy ship systems such as LHA, DX/DXG . . . Chaired the Summary and Critique Committee of the January 1967 Human Factors Quantification Symposium. Developed the specific recommendations contained in the Symposium Proceedings . . . Established liaison between the Council of Defense and Space Industry Association (CODSIA) and the DoD to investigate the feasibility of establishing human factors data banks. . , Lectured in School of Engineering at UCLA on "Systems Analysis/Systems Management: Aids to Decision Making." . . Provided technical direction and consultation for an operational test of the application of educational technology to aircraft maintenance on the Presentation of Information for Maintenance and Operation (PIMO) project.

1963-1966

. System Program Staff Officer in the Air Force Systems Command responsible for the formulation of Systems Management policy including Systems Engineering and Planning, Programming, and Budgeting (PP&B). . . Co-developed the concepts of and instituted the procedures in the Air Force for Contractor Data Management in weapon system acquisition which has been adopted by the Department of Defense (DoDD 5010.12). Eliminated well over 500 data generating documents on Air Force contracts with an estimated savings of 1-4% of weapon system acquisition costs. Awarded the Oak Leaf Cluster to the Air Force Commendation Ribbon for this activity. . . Integrated Contractor Data Management with Systems Management in the weapons system environment. Briefed some 7500 managers at over 55 aerospace contractor plants on the concepts and application of Systems Management. . . At the request of the Canadian Government, conducted a training program for their Department of Defense Production Board on Systems Management including PP&B. This program was given to approximately 150 key Canadian officials. . . Developed a television program entitled "ABC's of Systems Management." This has been shown to well over 750 audiences throughout the United States, Germany, England, and Canada. . . Taught each Air Force System Program Office (SPO) class the intricacies of Systems Management. . Have acted as consultant to the SPO's on Data and Systems Management matters. . . Developed a total management plan to address the problem of standardization as a function of system design. This procedure is being adopted by the Army and Navy as well as the Air Force. A 76 percent reduction in unique electronic parts on one major missile system has resulted in a cost avoidance of approximately $130 million. Received a Certificate of Merit from both General Schriever, Systems Command, and General Hobson, Logistics Command, for this accomplishment. . . As Consultant to the Assistant Secretary of Defense (Manpower) in the development of the Comprehensive Training and Education Program (CTEP) Study, aided in the systems application of new instructional technologies and methodologies, including computer based instruction and educational television. . . Lectured at the National Science Foundation supported Scientific and Technical Communication Symposium at Colorado State University.

1958-1961 . Associate Professor of Behavioral Sciences, United States Air Force Academy. Organized and taught the first Academy courses in General Psychology, Leadership and Management. Wrote four management cases which have been published and are being used by the Academy and the Air University. . . Developed course outline for the first Human Engineering course at the Academy. . . Planned, instituted and supervised the first Management Studies Laboratory. . . As Course Director of Managerial Psychology, developed curriculum, conducted in-service education of faculty and evaluated learning outcomes. . . Developed a Cadet Rating Scale and a Characteristic Profile Scale employing factor analysis techniques. Both scales were made amenable to computer handling.

1955-1958 . Commander, Special Weapons Jet Fighter Squadron Japan. Responsible for knowledge about targets, aircraft, and nuclear weapons. Integrated maintenance planning and operational requirements to sustain the highest aircraft availability of the squadron in the Far East. The squadron flew consistently 1000 hours a month with 25 aircraft. . . Trained and qualified bomb commanders to cover nuclear targets in two months less time than authorized. . . Developed education and athletic program for squadron which contributed to an improved re-enlistment rate of 23 percent.

51-1955 . Assistant Professor, Department of Air Science University of California (Berkeley). Conducted junior and senior seminars in Problem Solving, Leadership and Management Theory and Theory of Small Groups. . . Conducted independent research on the effect of audio-visual aids upon the learning process. . . Was consultant to the Commander of the Air University in the development of the Air Force Leadership Manual.

1950-1951 . Director, Training Analysis and Development in the Air Training Command. Revised academic curriculum and flight instruction methodology in the Air Force Pilot Instructor School resulting in a 10 percent performance improvement by the trainees. . . As Training Equipment Specialist conceived, tested and procured presentational aids for use in flight training ground school instruction. The improvement in student grades was significant at the one percent confidence level.

education UNIVERSITY OF ARIZONA Tucson, Arizona

1961-1963 . Master of Science (M.S.) Degree in Aerospace Engineering in June 1963. Majored in Aeornautical Engineering with a minor in mathematics. Took overload courses in Systems Analysis and Computer Design, Engineering Law and Machine Tool Engineering. Wrote Master's thesis on Experimental Investigation of the Coanda Phenomenon---Deflection of a Jet Stream along an Unbound Surface.

UNIVERSITY OF CALIFORNIA Berkeley, California

1951-1955

. Doctor of Philosophy (Ph.D.) in Educational Psychology in June 1954. General program of studies with a view to furtherance of understanding broad area of management. Basic building blocks included Learning Theory, Personality Theories, Psychometrics, Perception, Motivation, and Psychology of Individual Differences. Specialization included Interpersonal Relations, Group Dynamics, Theory of Small Groups, Human Relations in Management, Statistics and Experimental Design. Was awarded a Master of Arts (M.A.) Degree in Educational Psychology in 1953.

UNITED STATES MILITARY ACADEMY West Point, N. Y.

1945-1949

. Bachelor of Science (B.S.) Degree. General engineering education with a balance of social sciences and humanities. Graduated in top third of class. First in the class in the study of French. Major "A" for varsity track team for the hammer throw. Member freshman boxing team. Member of the handball club three years; president, senior year.

early background

. GREW UP IN METROPOLITAN NEW YORK. Attended public, elementary and high school grades, in New York, graduating from Townsend Harris High School as salutatorian. Elected to the National Honor Society. President of the senior class; class representative to the student legislature. Member of varsity chess and handball team. Boxed in the 155-pound class. Entered college at the age of 15 1/2.

& outside interest

. Consulting with the local public school in applications of programmed instruction and educational technology. Associate Lecturer at George Washington University teaching a graduate course entitled "Human Relations in Management" in the General School of Business and Personnel Administration. Enjoy sailing, fishing, camping, and handball when time permits.

. RECENT PUBLICATIONS:

An Operationally Validated Concept for Improving System Effectiveness, proceedings of the Sixteenth Conference of the Society of Technical Writers and Publishers, May 15, 1969.

Procedures for Determining Operational Qualitative and Quantitative Personnel Requirements, Triner, Eberhard, and Byrnes, for Human Performance Technology Center, Bell Telephone Laboratories, Serendipity Associates, February 1969.

Criteria and Methodology for Input and Output Device Selection and Format Design. Triner, Kolkowitch, Kolsrud, Evans, for Bell Telephone Laboratories, Serendipity, Inc. June 1969.

Basic Technical Data Storage and Retrieval Program (BTDS), Triner and Siciliani, for Army Materiel Command, Technical Data Centers, Serendipity, Inc. January 1969.

Performance Concept for Housing for the National Bureau of Standards, Serendipity Associates, July 1968.

A Systems Approach Applied to a Technical Data Problem - Symposium Preceedings of the American Ordnance Association - 10th Annual Meeting, May 1968.

Fire Research and Safety Center Implementation Plan for the National Bureau of Standards, Serendipity Associates, Dec. 1967.

Fire Research and Safety Center Planning Concepts for the National Bureau of Standards, Serendipity Associates, Sept. 1967.

Application of the DoD Programming System at the Level of the Research Division. Serendipity Associates, 1967.

Systems Analysis/Systems Management: Aids to Decision Making. School of Engineering, UCLA, course entitled "Application of Value and Criterion Function Theory to Engineering Design," January 1967.

People - The Nation's Most Precious Resource, Monograph, OASD (SA), September 1966.

Information for Maintenance and Operation, Computer Based Information and Instructional System - Proceedings of the Engineering Systems for Education and Training Conference - DoD Office of Education - NSIA.

PIMO - Retrospect and Prospect, Proceedings of the 1966 Society of Technical Writers and Publishers Convention, May 11, 1966.

Engineering Design - Key to Logistics Management, Technical Report of the American Ordnance Association, April 27, 1966.

Blue Print for Standardization Management in Accordance with System Management Procedures, Monograph, Hq AFSC Press, March 28, 1966.

Advanced Technical Manual Technology, 8th Annual Institute in Technical and Industrial Communication, Colorado State University, July 6, 1965.

The Management and Science of Manual Development for Integrated Logistic Support - Technical Manual Management, Proceedings of the DoD - NSIA Symposium, June 1965.

Technical Manuals in Transition, Proceedings of the 12th Annual Society of Technical Writers and Publishers Convention, May 19, 1965.

Systems Management Control & Education, Proceedings of the AFSC Commanders Conference, April 1965.

Data Management - Present and in Prospect, Proceedings of the Air Force - Industry Data Management Symposium at Dayton, Ohio, Oct. 20, 1964.

Air Force Objectives and Progress in Advanced Technical Manual Technology, Proceedings of the 1964 DoD- Industry Symposium of the NSIA Maintenance Advisory Committee.

Air Force Technical Manual Technology in Prospect, Symposium Proceedings of the ORSA/STWP 10th Annual - 1st International Meeting, Sept. 18, 1964.

A Critical Look at Managerial Psychology Instruction at the U.S. Air Force Academy, Monograph, Department of Behavioral Sciences, U.S. Air Force Academy, May 1960.

Operation Third Lieutenant - An Evaluation, Monograph, Department of Behavioral Sciences, U.S. Air Force Academy, April 1959.

VITA

JOHN V. ZUCKERMAN

4040 San Felipe Road, Apt. 24B
Houston, Texas 77027
713 622-3140

September, 1969

EXPERIENCE

1969: Appointed Professor and Chairman, Department of Behavioral Management Science, College of Business Administration, University of Houston, in September, 1969.

1963-1969: Director, Research and Development Systems Management Program, and Associate Professor of Management, University of Southern California. First Director of Master of Science Program under contract to AIR Force for officers and civilians with undergraduate education in engineering and science. Seven classes have produced 183 graduates; one class of twenty will receive the master's degree in 1970. Developed curricula, reorienting program to emphasize quantitative tools for decision-making and applications of behavioral sciences in systems management environments. Devised research projects course involving students in field analysis work in industry and government R&D management organizations. Directed research to develop three major systems management cases. Conducted research evaluation of use of a large-scale computer simulation of organization as a system management training means. Completed research to develop ten issue cases in financial management in the Air Force.

Chairman, Department of Management, 1964-1966; twenty-three full-time, ten part-time faculty members. Augmented faculty with science-trained personnel; stressed experimental research in management. Planned management laboratory and recruited director. Introduced advanced courses in organizational development into graduate curriculum.

Consultant in management and the application of behavioral sciences. Frequent lecturer to business, government and educational groups. Recent Studies:

Government -- in 1967, completed an evaluation of the doctoral education program in humanities and sciences for the Assistant Secretary of the Air Force (Manpower and Reserve Forces). In 1968, completed a study of comptroller education and future roles of comptrollers for the Assistant Secretary of the Air Force (Financial Management).

Business -- Top management and organizational succession studies; human resources inventory; criterion development for incentive contract management evaluation; aerospace company material management; research and development management in an earth sciences company; establishment of social sciences application group. Among clients: Hughes Aircraft Company; Aerojet General Company; Humble Oil Company; Wells Industries Corporation (Director, 1966 to 1967); Dames and Moore.

Education -- Consultant to the President, Cleveland State University, 1967, on long-range plan for the College of Business Administration.

Consulting Staff Assistant to the Manager, Systems Applications, System Development Corporation, 1963-1967. Charted a plan to study SDC technology as it applied to defense and non-defense utilization. Completed a corporate-wide study on simulation technology. Conducted exploratory development on the use of computer-based organizational simulation for management training. (Part-time appointment)

1961 to 1963: Deputy Director, Bureau of International Business Operations, U.S. Department of Commerce. Direct appointment, FSR-2, Foreign Service Reserve, with assignment to direct U.S. trade promotion and commercial intelligence activities world-wide. Direct-line supervisor of an 800-employee unit. Responsible for trade fairs, centers, and missions. Directed trade fairs in developing countries for U.S. information Agency.

Sponsored the first systems analysis study of the flow of international commercial and economic information which led to automation and streamlining of services in the State and Commerce Departments. Supervised Brookings Institution Senior Public Affairs Fellows from industry in an organizational study which was implemented by Secretary Hodges. Appointed Acting Director of the Bureau and thereupon recommended its consolidation with the Bureau of International Programs into the Bureau of International Commerce. Completed consolidation and was named Director of International Trade Promotion in the surviving Bureau.

1960 to 1961: Regional Sales Manager, Ampex Magnetic Tape Products Division, Ampex Corporation. For one year, as part of personal career development plan, managed a five-state region, including Washington, D. C. Established manufacturer's representatives, selected industrial distributors, made direct sales to government offices. Negotiated for approval of Ampex Computer tape on the buying lists of the General Services Administration. Tripled sales volume in one year, against the competition of the 3M Company which held 85% share of the market.

1955 to 1960: Corporate Director of Personnel and Industrial Relations, Ampex Corporation. When company had 500 employees, began as head of plant engineering, offices services and employee/labor relations. As company grew in 4½ years to 5000 employees, developed industrial relations activities into the full array needed in a growth company based on technology. Supervised up to 125 employees.

Some highlight achievements -- Negotiated a joint program of job grading with the International Assn. of Machinists which became a landmark contract, permitting changing craft union grades into industrial grades for electronics and complex-electro-mechanical operations. When company was divided into six autonomous divisions, decentralized personnel operations, kept small policy staff. Directed corporate data processing activity during early acquisition of random access memory unit. Guided document storage and retrieval study leading to establishment of technical information service at corporate level.

1948 to 1955: Research Scientist and Research Administrator. Army, Navy and Air Force sponsored programs. Conducted field experiments on audio-visual learning and military training at Great Lakes Naval Training Station (Pennsylvania State University Instructional Film Research Program, under contract to ONR).

Completed field evaluations of learning from training films on the F-86A aircraft at 14 Air Defense Command locations. Designed and carried out at Williams AFB a predictive experiment to improve instructional film-making methods (Human Resources Research Laboratories, U.S. Air Force).

Directed projects in psychological warfare research for the Army; planned and reported research progress as Assistant to the Director, Human Resources Research Office. (The George Washington University, under contract to the Army).

1947 to 1948: Director, Radio Workshop and the Audio-Visual Aids Program, Stanford University. Implemented faculty committee study to increase use of audio-visual technology in instruction at the university level. Prepared recommendations for establishment of a university-wide audio-visual service facility. As additional duty, taught courses in radio broadcasting in the speech and drama department. Monitored student broadcasting station. Taught in summer institutes co-sponsored by National Broadcasting Company.

MILITARY SERVICE

Enlisted in Army Signal Corps Reserve, 1942. Completed radio and electronics physics courses as civilian employee. Called to active duty in 1943, assigned to Office of Strategic Services. Taught and handled administrative duties in communications schools. Assigned to Signal Corps Officer Candidate School, commissioned 2nd lieutenant, 1944, and returned to OSS. Supervised classified propaganda operation in U.S. and Saipan. In 1945, served as Chief, Shortwave Operations Section, Armed Forces Radio Services. Reduced staff one-third while maintaining wartime level of operations, through 1946. Captain, U. S. Army Signal Reserve, transferred to U.S. Air Force Reserve in 1948. Mobilization designee, Human Factors Division, Deputy Chief of Staff for Development Headquarters, U.S. Air Force, 1951-53. Resigned commission in 1953.

EDUCATION

1949 to 1951: Stanford University, California - Doctor of Philosophy, in psychology, April 1951. Studies in experimental, social and industrial psychology, minor in Asiatic and Slavic studies and Russian language. Major fields: learning theory, personality theory, psychometrics. Specialization: personality measurement methods and experimental design. Elected to Sigma Xi.

Graduate Research Assistant, sponsored by Department of the Army Medical Specialists Research Project.

1947 to 1948: Stanford University, California - Master of Arts, in psychology, August 1948. Combined undergraduate and graduate program without undergraduate degree. Major Fields: social psychology, psychology of art and music. Specialization: Measurement of the effects of mass communication media on attitudes. (University faculty member, as indicated above). Honorary member, student dramatic society, Ramshead.

1939 to 1942: University of Chicago - Freshman and sophomore studies in sciences, humanities. Senior and graduate courses in electronics physics and mathematics, sponsored by U.S. Army Signal Corps. Ranked sixth in class of eighty.

ORGANIZATIONS

Fellow, American Psychological Association and American Association for the Advancement of Science; Diplomate in Industrial Psychology of the American Board of Examiners in Professional Psychology. Member, Academy of Management, The Institute of Management Sciences; Beta Gamma Sigma, business honorary; Sigma Xi; psychologist, State of California.

PERSONAL DATA

Married: 3 children. 6 feet, 3½ inches, 220 pounds. Good health.

Avocations: Music and Theatre. Vice President, Director and percussionist, Brentwood Symphony Association. Enjoy hiking in the mountains when time permits.

Biographies in: American Men of Science; Who's Who in America.

Security clearance: TOP SECRET, Office of the Secretary of the Air Force.

SELECTED PUBLICATIONS

Testing with a pre-release filmstrip as a means of predicting factual learning from a training film.
Human Resources Research Laboratories, Department of the Air Force, Memo Report No. 10, 1951.

Interest test item response arrangement as it affects discrimination between professional groups.
Journal of Applied Psychology, Volume 36, 1952.

Medical Specialists Preference Blank (a test for personnel guidance purposes -- With co-authors Strong, Tucker, Holmen, Gary, Adamson.) Copyright 1952, Stanford University.

Commentary variations in instructional films; their effect on learning perceptual motor tasks.
Journal of Communication, Volume 2, 1952.

Improving the Utilization of Research Results: the Role of the Research Manager.

Presented to Working Conference on Research Program Effectiveness, Office of Naval Research, July, 1964.

Psychology should be useful. In Symposium: the Place of Psychology in Graduate Schools of Business Administration.
Presented to the American Psychological Association annual meeting, September, 1966.

Challenges for the future of program managers.
Presented to the Second Annual Symposium on Program Control, National Contract Management Association, March, 1967.

Management system training using Leviathan (A Complex Computerized Organization Simulation).
System Development Corporation (With co-author Holmen)
Technical Manual 3727, December, 1967.

Cases in Systems Management.
Three policy cases developed for the Air Force Institute of Technology, University of Southern California Research Institute in Business and Economics, December, 1966.

Cases in Financial Management in the Air Force.
Ten policy and issue cases developed for the Air Force Institute of Technology, University of Southern California Research Institute in Business and Economics, September, 1969.

University of Houston

Inter-Office Memorandum

To Dr. John Allred **From** D. Reginald Traylor DRT.

Dept. **Date** December 12, 1969

Subject NASA Grant NGR 44-005-021

The following information is submitted to you as per your request of September 30. The two statements below summarize research which was supported under NASA Grant NGR 44-005-021.

A. The main topic of the research was Schauder bases for functions analytic in multiply-connected regions in the plane. In a previous research effort (Polynomial Bases for Compact Sets in the Plane, Trans. Amer. Math. Soc., Vol. 132, No. 2, 1968, pp. 541-551) the present researcher investigated Schauder Bases of polynomials for functions analytic on compact sets whose complements are connected and possess Green's functions with pole at infinity. For such sets, Schauder bases of interpolation polynomials are easily constructed, the topology of the function space being an inductive limit topology. These absolute bases were used to consider effective polynomial bases, whose coefficient functionals are defined by infinite matrix multiplication.

In the research supported by the present grant, and in research immediately following upon this, attention was turned to multiply-connected sets. For any region D of finite connectivity, whose boundary consists of analytic Jordan curves, an absolute Schauder basis of rational functions, with poles in the complement of D, was constructed. (D was not assumed

bounded.) This absolute basis was used to consider effective bases of analytic functions on D, whose coefficient functionals are given by infinite matrix multiplication. Conditions for effectivity were derived, and a construction was given for extending a basis for a simply-connected set associated with D, to a basis for D. This research has been submitted for publication under the title: Analytic Function Bases for Multiply-Connected Regions.

Natural questions which arise from this research are the following: (1) Can the restriction of finite connectivity of D be dropped? The researcher is convinced that all theorems can be extended to the case that D possesses a Green's function. (2) Does every domain D have a Schauder basis of rational functions? The researcher feels that this is probably true, and may be able to be proved by considering D as an increasing union of domains of finite connectivity which possess Green's functions. (3) What subsets of the Cartesian product of several copies of the plane have Schauder bases for the analytic functions of several complex variables? The researcher is convinced that any polydomain, in which each factor possesses a Green's function, has such a basis, and that perhaps any polydomain has a basis. (4) What subsets of the Cartesian product of countably many copies of the plane have Schauder Bases for the analytic functions of infinitely many complex variables? The researcher feels that a method for dealing with analytic functions of infinitely many complex variables can be evolved which will free them from the necessity of being locally functions of finitely many variables. (5) What are Schauder Bases for the set of functions continuous on a compact set K and analytic at each interior point of K, with the sup norm topology?

B. (1) It was shown that if M and N are compact topological spaces and μ and ν nonnegative regular Borel measures on M and N, respectively such that $\mu(M) > 0$ and $\nu(N) > 0$, and if h and k are positive and continuous on $M \times N$, then there exist functions f and g positive and continuous on M and N, respectively and a number $c > 0$ such that $\int_M fhgd\mu = 1$ on N and $\int_N fkgd\nu = c$ on M. f, g, and c depend continuously on h and k. As a consequence the following theorem holds: Let A be a positive $N \times M$ matrix and let $r_1, \ldots, r_n, c_1, \ldots, c_m$ be given positive numbers with $\sum_i r_i = \sum_j c_j$. Then there exist diagonal matrices D_1 and D_2 with positive main diagonals so that D_1AD_2 has row sums r_i and column sums c_j. The matrix D_1AD_2 is unique. D_1 and D_2 are unique up to a scalar multiple.

It was shown that if A is an $N \times N$ nonnegative fully indecomposable matrix whose positive diagonal products are equal, there exists a unique positive $N \times N$ matrix B of rank one such that $b_{ij} = a_{ij}$ if $a_{ij} > 0$. As a consequence it follows that a doubly stochastic matrix is characterized by its diagonal products: no two doubly stochastic matrices has proportional diagonal products.

This latter research led to the discovery of the concept of the nearly decomposable matrix from which a conjecture of Marshall Hall was settled in the affirmative: let A_N^k denote the set of $N \times N$ (0,1) matrice, with k ones in each row and each column. Then $\lim_{N\to\infty} \operatorname{Min}_{A\in A_N^k} \operatorname{per} A = +\infty$ if $k \geq 3$. This would follow from the famous Van der Waerden conjecture which states that $\operatorname{Min}_{A\in\Omega_N} \operatorname{per} A \geq \frac{N!}{N^N}$ where Ω_N denotes the $N \times N$ doubly stochastic

matrices. Hall's conjecture was proved true independent of the truth of the Van der Waerden conjecture.

It has been further shown that if A is $N \times N$ nearly reducible and doubly stochastic, then A is necessarily a full cycle permutation matrix. As a consequence it is shown that for A nearly decomposable (0,1), per $A \leq 1$.

(2) Theses and Dissertations.

Three masters theses:

"An investigation of the relationship between arbitrary positive matrices and doubly stochastic matrices". (Jack William Crosby, 1967).

"Nonnegative matrices with prescribed row and column sums". (Jean Rogers Edwards, 1968), and

"Concerning the set of doubly stochastic positive semidefinite matrices". (John Raymond Monroe, 1969),

and one PH.D. dissertation

"On the structure of certain matrix classes", (Darald J. Hartfiel, 1969), has resulted directly from this research. Three students, Edwin Roberts, Jack Crosby and Mark Hedrick are considering dissertation problems connected with this research.

(3) Publications.

1. "A note concerning simultaneous integral equations" (with Paul Knopp) Canadian J. of Math., 20 (1968), 855-861.

2. "Problems involving diagonal products in nonnegative matrices" (with Paul Knopp) Trans. Amer. Math. Soc., 136 (1969), 67-75.

3. "Concerning a conjecture of Marshall Hall", Proc. Amer. Math. Soc., 21 (1969), 197-201.

4. "Concerning nearly decomposable doubly stochastic matrices" (with Mark Hedrick) submitted to the J. of Algebra.

(4) Research Status.

The D_1AD_2 is solved for positive matrices but is not completely settled for nonnegative matrices. Work is to be continued to find for which such matrices the D's exist and if they can be obtained constructively when they do exist.

Since the "fill in" matrix problem is solved for the case in which the Nth order symmetric functions of the positive diagonals are equal, it would be of interest to study the same questions for lower order symmetric functions. A partial result has already been obtained by Mark Hedrick for the first order function.

The fact that the Marshall Hall theorem is true gives little insight into the Van der Waerden problem. The Van der Waerden conjecture, for example, shows that $\overline{\lim_{N\to\infty}} \min_{A\in A_N^k} (\text{per } A)^{\frac{1}{n}} \geq \frac{k}{e}$ if $k \geq 3$ while estimates obtained for the Hall conjecture only show that $\lim_{n\to\infty} \min_{A\in A_N^k} (\text{per } A)^{\frac{1}{n}} \geq 1$.

Work will be carried on to improve this estimate -- even perhaps to the extent of settling the Van der Waerden problem.

Hedrick has shown that if A is a nearly indecomposable (0,1) matrix and P is a permutation matrix so that PA has a positive main diagonal, then PA - I is nearly reducible and thus per (PA - I) $\leq$ 1. Nevertheless

almost nothing can be said as yet about per A = per PA. Work will be continued in this direction.

It would be of special interest to know the cycle structure of the positive diagonals of matrices in A_N^3. This would help make clear many of the problems connected with upper and lower bounds for permanents of Marshall Hall matrices. It should give a great deal of insight into the Van der Waerden problem -- a conjecture which has remained unsettled since 1926!

CHEMICAL ENGINEERING

The NASA supported program being carried out in the Chemical Engineering Department includes analytical and experimental studies directed toward development of entirely new measurement techniques and interpretation of the results obtained.

Much progress has been made toward the experimental phase of the project. Extensive measurements (1) of the turbulence properties have been made for a rough surface (triangular shape) using a conventional anemometer and reliable data has been obtained (2) with the laser anemometer for smooth surface channel flow.

The laser anemometer system has been further modified during this period to improve the quality of data and to reduce the difficulty in making measurments. Attached as an appendix is the mathematical development of the techniques involved in these modifications. In addition to improvement in the electronic data processing, a more reliable, narrow range particle generation system (developed at NASA, Marshall Center, Huntsville, Ala.) has been included. Work will continue on these and other points in order to reduce the difficulty in acquiring the high accuracy data needed to carry out this study.

Data for the turbulence properties obtained from the laser anemometer are presented in Figures 1, 2, 3 and 4.

Figure 1 presents a comparison of turbulence intensities (axial, u' and normal v') as a function of position. Good agreement with hot wire anemometer measurements is apparent.

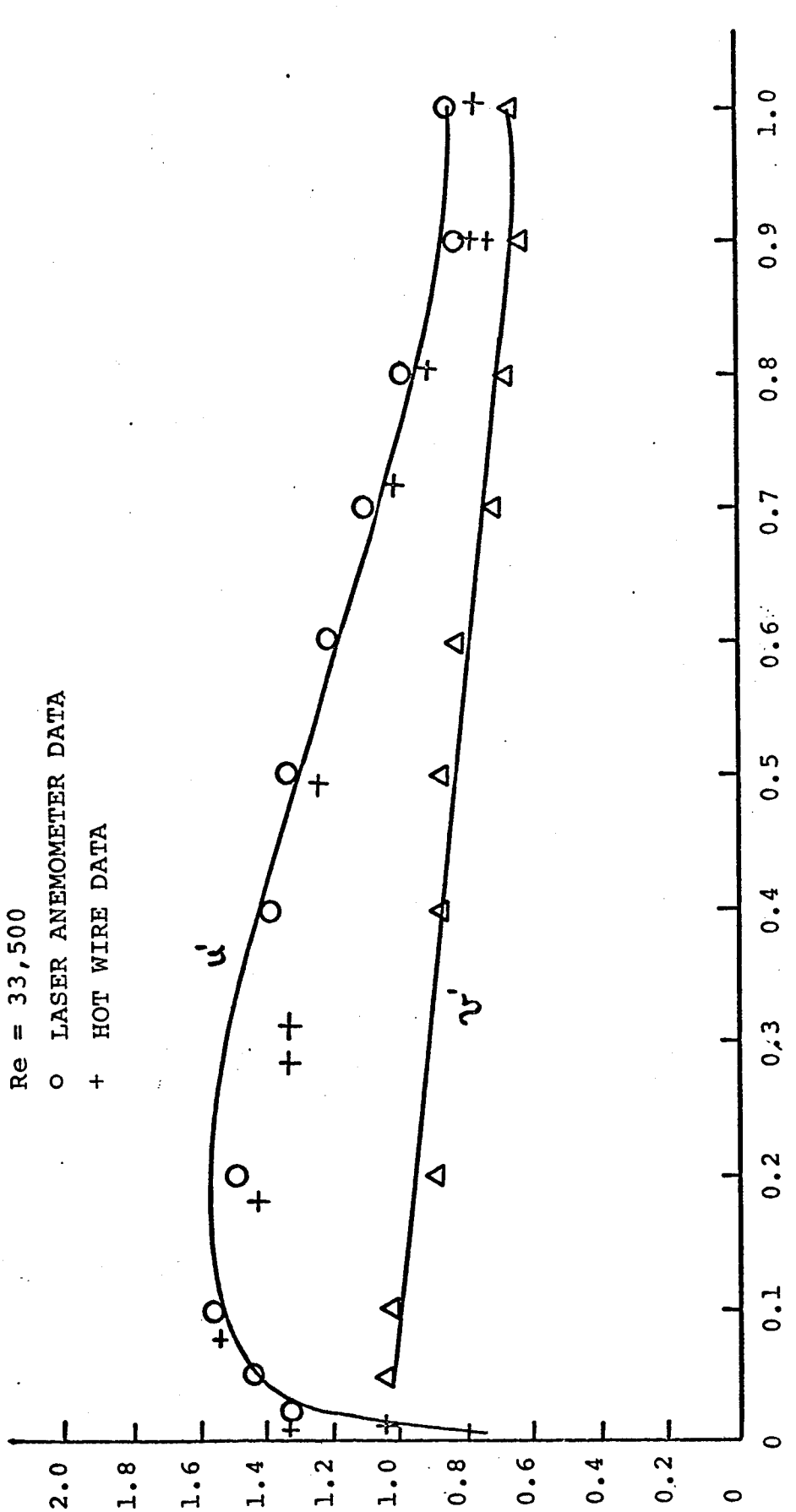
GAS FLOW
RECTANGULAR CHANNEL ~ 2" X 26"
Re = 33,500
o LASER ANEMOMETER DATA
+ HOT WIRE DATA
u'
v'
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Y/B
u'/U*

FIGURE 1

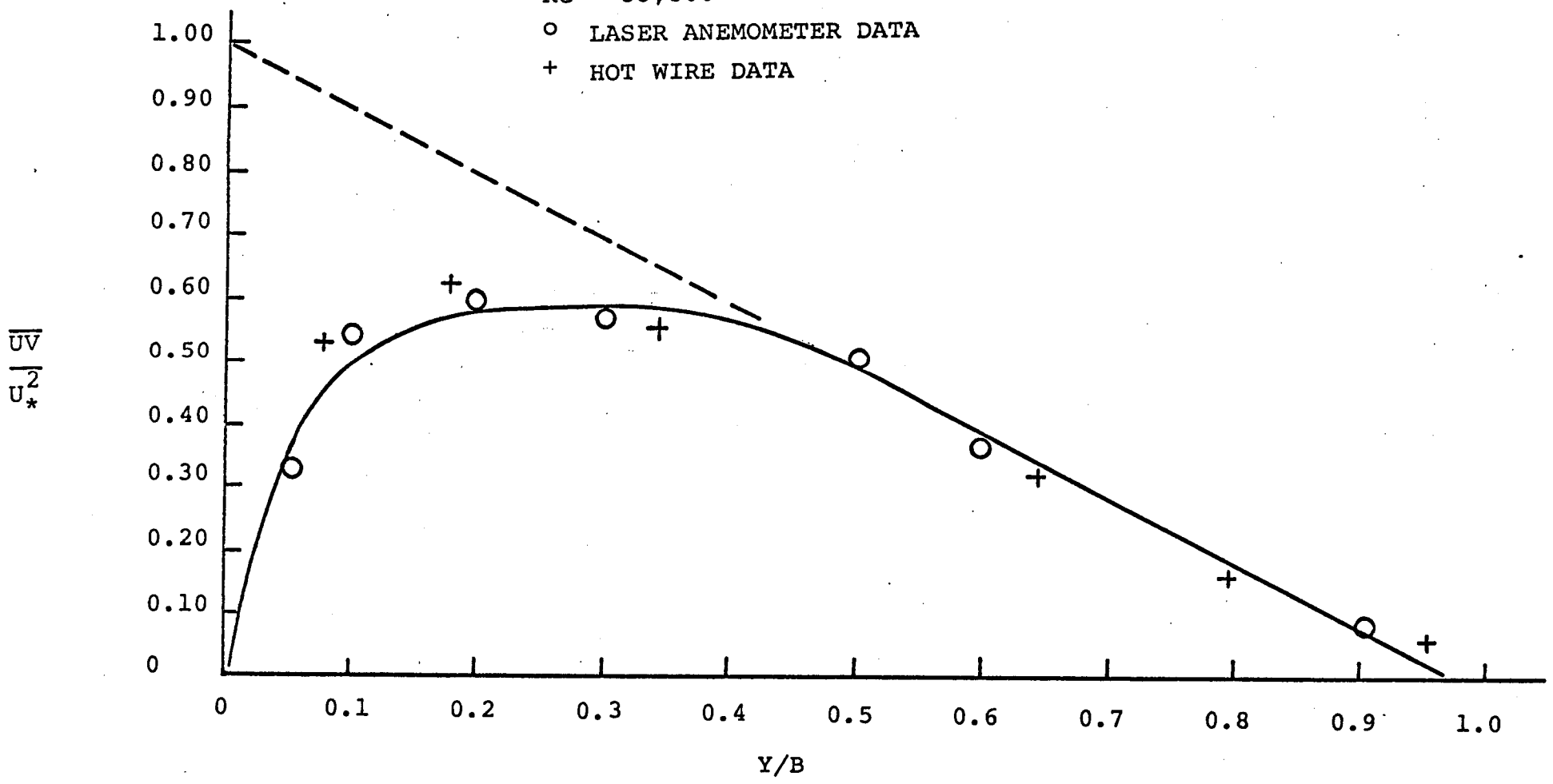
GAS FLOW
RECTANGULAR CHANNEL ~ 2" X 26"
Re = 33,500
o LASER ANEMOMETER DATA
+ HOT WIRE DATA
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0
UV / U*2
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Y/B

FIGURE 2

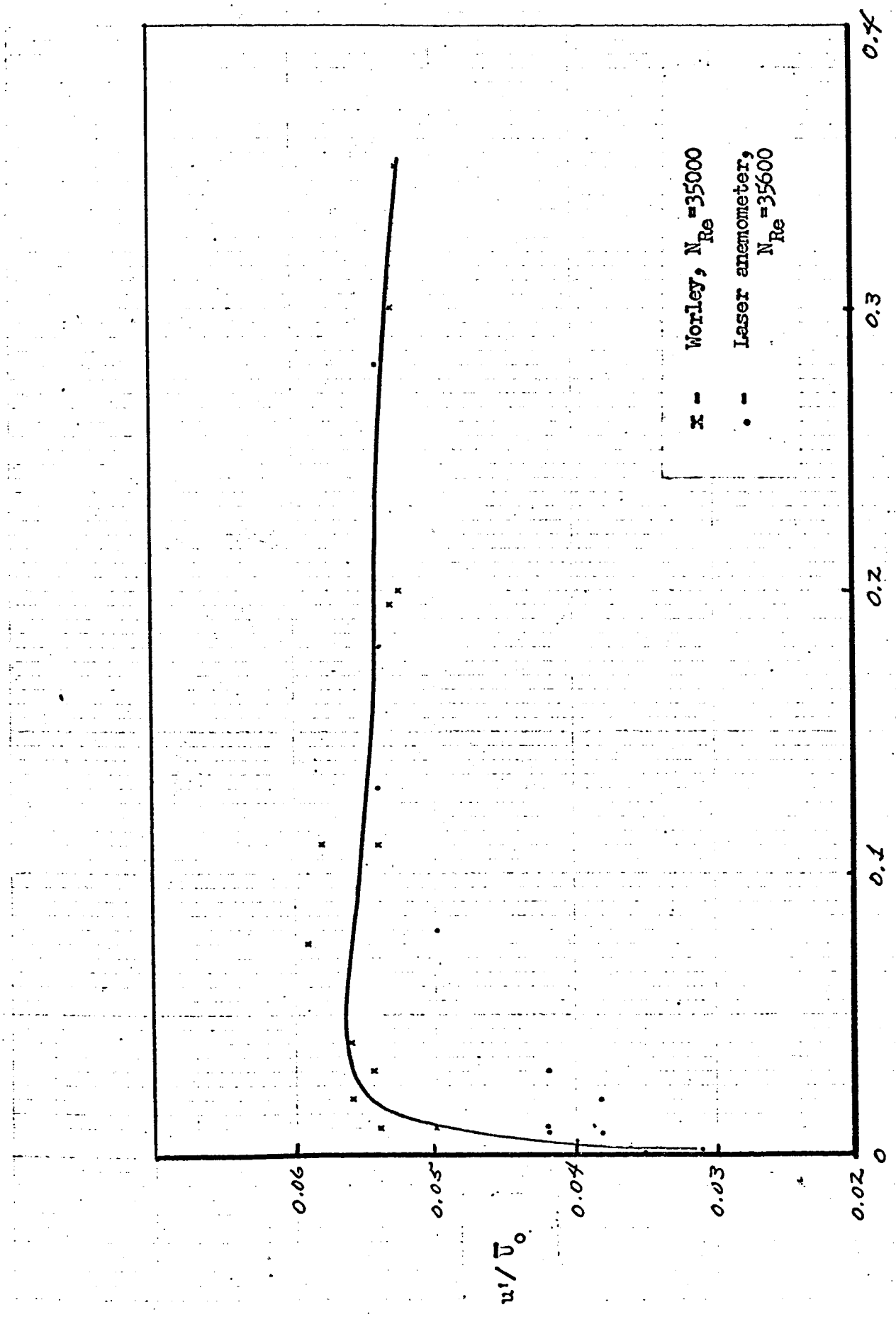

Figure 3. Turbulence intensity profile, u'/ $\bar{U}_o$ vs. y/ B.

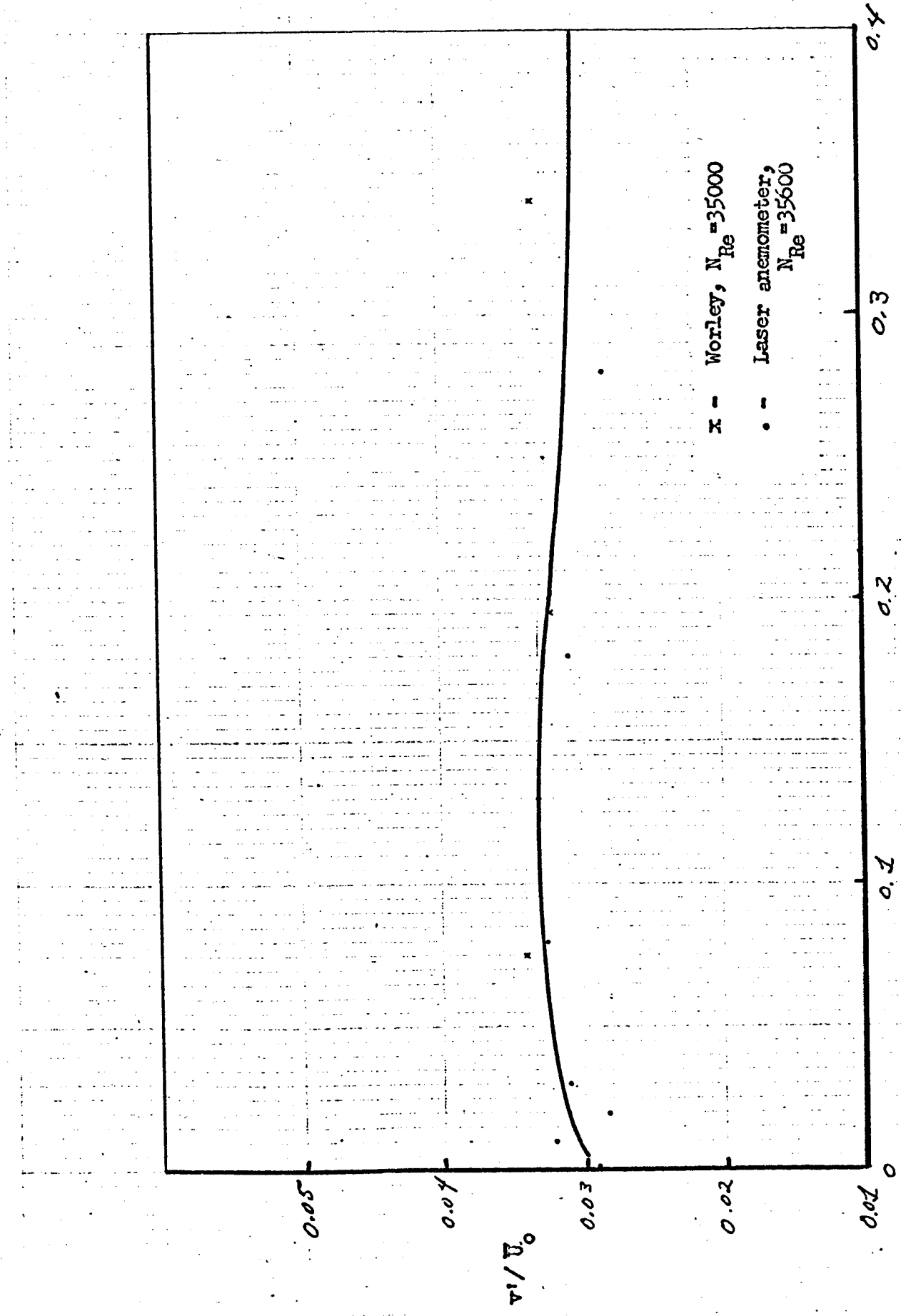

Figure 4. Turbulence intensity profile, v'/U_o vs. y/B.

Figure 2 shows $\overline{uv}/u_*^2$ (shear stress ratio) results for a slightly rough surface (oil droplets) as measured by both hot wire and laser anemometers. Figures 3 and 4 are preliminary results obtained in the wall region. These data will be further processed to improve the accuracy. This is necessary as the turbulence is intermittant in this region and long integration times are needed to obtain a reliable average value. The equipment necessary to do this will be available shortly.

The rough surface measurements, using the hot wire anemometer, were made over a triangular roughness (1/4 inch peak to valley, wave length 1.0 inch) in a rectangular flow channel of 13:1 as pect ratio. Measurements included mean velocities ($\overline{U}$, $\overline{V}$), turbulent fluctuating velocities (u', v') and one component of the shear stress tensor, $\overline{uv}$. In addition, estimates were made of the turbulence scales by using the energy spectra. The effects of axial and normal position as well as Reynolds number were investigated.

One result of this study is the determination that similarity, as applied to smooth surfaces does not apply to this rough surface. The primary limitation lies in the failure to include the effect of normal, mean velocity gradients which necessarily result from flow over rough surfaces. It appears that all attempts to adjust the shear velocity, u_*, to achieve similarity are neglecting the primary issue. That is, it must include a roughness parameter which accounts for the contribution of the non-axial or secondary type flow noted above. In addition, it is also apparent that the use of the shear stress, $\overline{uv}$, deviation (or Δu^+ idea) from smooth surface value will not generally be useful. Although

form drag is certainly present; its effects are innately included in the momentum equation and is thus accounted for is all quantities are known.

This study further confirms that the region ($y \leq 0.2D$), including the valley area between roughness elements must be extensively explored in order to develop predictive techniques which will account for the roughness effect.

Present plans are to use the laser anemometer to make extensive measurements in this region and to proceed at the same time with the analytical studies already underway.

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3) Worley, F. L., Jr., et al, "The Practical Application of the Laser Anemometer for Fluid Flow Measurements", Proceeding of the Electro Optical Systems Design Conference, Sept. 1969.

APPENDIX

PRINCIPLE OF OPERATION

A number of optical arrangements can be utilized for both single and multiple component fluid velocity measurements. The optical system utilized to obtain the one component data presented herein is shown schematically in Figure 5. Light of wavelength λ emitted from the laser is focused to a position in the flowing fluid by means of lens L_1. From this position a small portion of the beam is scattered through angle θ. The scattered light, shifted in frequency because of the Doppler effect, is collected by lens L_2, passes through the beam splitter and is focused on the photocathode surface. The unscattered portion of the laser beam is collected by lens L_3, attenuated by a neutral density filter, reflected at the front surface mirror M_1 and rotated by the beam splitter. The beam splitter and the mirror are adjustable and are used to align the incident beam (unscattered light) with the scattered light. The two beams are made to coincide in the region between the beam splitter and the photomultiplier tube. When the foregoing conditions are obtained optical homodyning occurs and one notes an AC output from the photomultiplier tube. If the sine wave is monitored with an oscilloscope, and the neutral density filter is adjusted to produce the maximum signal to noise ratio, the optimum incident beam to scattered beam intensity ratio and maximum homodyning efficiency will have been obtained.

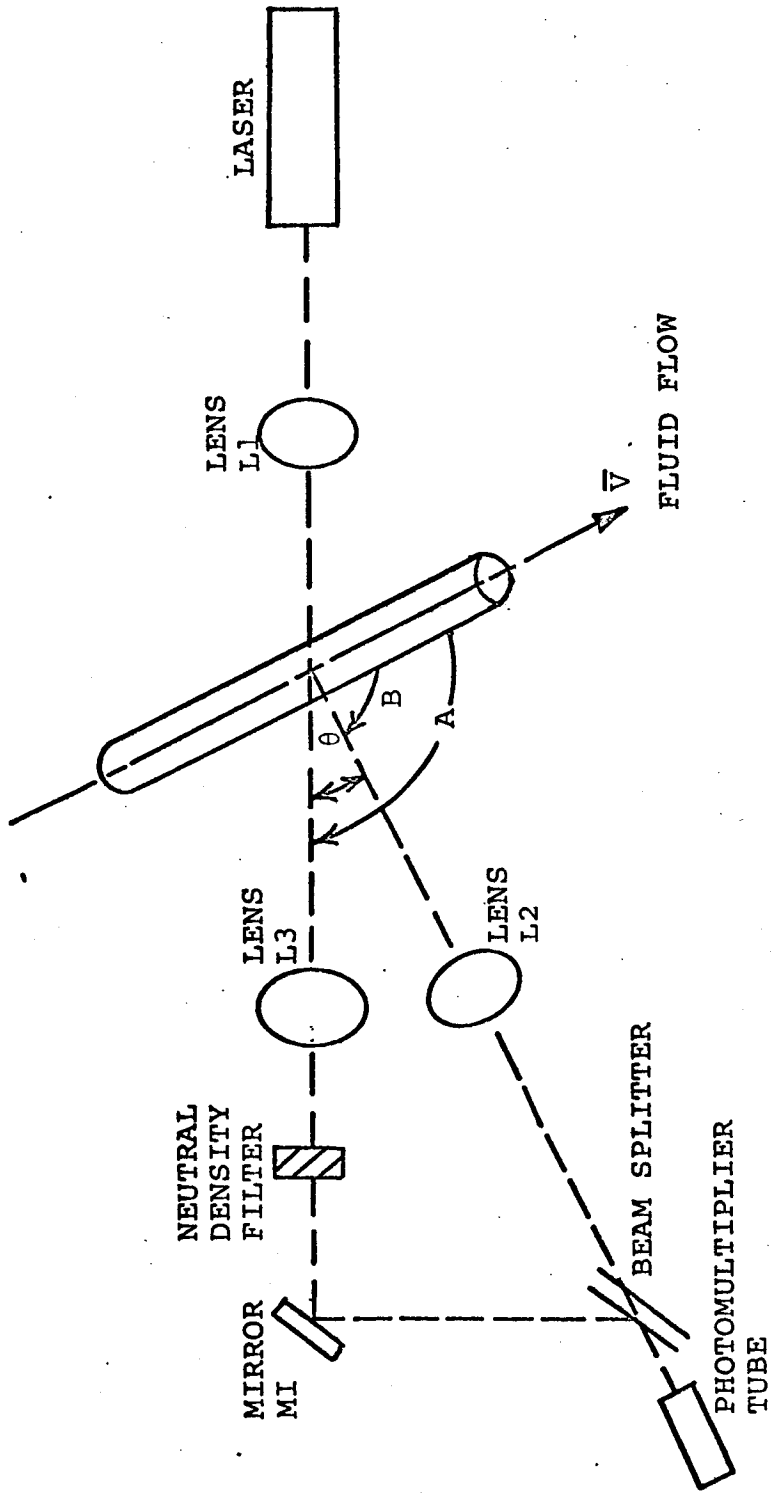

FIGURE 5

SCHEMATIC DIAGRAM OF TYPICAL LASER ANEMOMETER SYSTEM

The Doppler shifted frequency, f_D, from a scattering, center fixed in a reference frame which has a velocity relative to a laboratory fixed frame is given by

$$f_D = \frac{1}{2\pi}\left\{\hat{K}_s - \hat{K}_o\right\}\cdot\hat{V} \tag{1}$$

where $\hat{K}_s$ and $\hat{K}_o$ are the wave vectors of the scattered and incident radiation respectively. For nonrelativistic motion

$$|\hat{K}_s| = |\hat{K}_o| = K$$

and $$K = \frac{2\pi n}{\lambda}$$

where λ is the wavelength of the incident radiation and n is the index of refraction of the media. Substituting into Equation (1) one obtains

$$f_D = \frac{n}{\lambda}\left\{\cos B - \cos A\right\}V$$

$$f_D = \frac{n}{\lambda}\left\{\sin\theta\right\}V \qquad \text{when } A = \pi/2 \tag{2}$$

where the angles A and B are defined in Figure 5.

The frequency of the scattered light entering the homodyning region is therefore

$$f_s = f_o + f_D \tag{3}$$

Where f_o is the frequency of the incident beam emitted from the laser. Light with frequencies f_o and f_s are made coincident in the homodyning region. Partial homodyning results in signals corresponding to the following equations

$$E_1(t) = E_0 \cos 2\pi f_0 t$$
$$E_2(t) = E_0 \cos 2\pi f_s t$$
$$E_3(t) = E_0 \cos 2\pi f_0 t \cdot \cos 2\pi f_s t \qquad (4)$$

The last of this set is, of course, equivalent to two signals with frequencies equal to the sum and difference of the original frequencies.

$$E_3(t) = \frac{E_0}{2} \cos 2\pi (f_s + f_0) t + \frac{E_0}{2} \cos 2\pi (f_s - f_0) t$$

So, under ideal conditions, four signals represented by the following equations are received by the photomultiplier tube.

$$E_1(t) = E_0 \cos 2\pi f_0 t$$
$$E_2(t) = E_0 \cos 2\pi f_s t$$
$$E_3(t) = \frac{E_0}{2} \cos 2\pi (f_s + f_0) t \qquad (5)$$
$$E_4(t) = \frac{E_0}{2} \cos 2\pi (f_s - f_0) t = \frac{E_0}{2} \cos 2\pi f_D t$$

The first three frequencies are 5×10^{14}, 5×10^{14} and 10^{15} cycles per second respectively, which is beyond the range of the photomultiplier tube. The fourth frequency ($f_s - f_o = f_D$) is proportional to the velocity of the scattering particle and the angle θ, and lies within the response range of the photomultiplier tube. Therefore, the photomultiplier tube acts as a low pass filter as well as a light to AC signal converter and amplifier. In the ideal case the output of the photomultiplier tube is therefore

$$E_{PM}(t) = E^{\circ} \cos 2\pi f_D t \qquad (6)$$

Of course, an ideal signal conforming to Equation (6), is not recovered from the photomultiplier tube. First the signal contains random noise which is predominantly photomultiplier tube shot noise and noise produced by non-homodyned light that reaches the photocathode. Equation (6) is modified to include this condition as follows

$$E_{PM}(t) = E^{\circ} \cos 2\pi f_D t + N(e) \qquad (7)$$

Second the signal contains random amplitude modulation that primarily results from the phase difference in light scattered by particles at different axial positions in the sampling volume. Although the diameter of the sampling cross section is restrained with apertures to 2×10^{-4} inches the focal depth ranges from 3×10^{-3} to 10×10^{-3} inches. The latter dimension is determined by the scattering angle and the optics and the optical arrangement used to focus the incident beam. If one notes the difference in the path length of incident light scattered from the extremities of the focal depth, one readily ascertains that a difference of several wavelengths exists under optimum conditions. Since the distribution of particles in position and time is mutually Gaussian, a Gaussian distribution of interference is produced in the homodyned signal. This appears as random amplitude modulation in the output of the photomultiplier tube. Equation (7) is modified to include this condition as follows

$$E_{PM}(t) = E^{\circ} \cos 2\pi f_M t \cdot \cos 2\pi f_D t + N(e) \qquad (8)$$

where f_m is the amplitude modulation frequency.

An additional problem that results from small number statistics that characterize scattering from sampling volumes utilized in laser anemometry, is amplitude variation. This condition is partially represented mathematically by modifying Equation (8) as follows

$$E_{pm}(t) = E^{\circ}(1 + \cos 2\pi f_a t)\cos 2\pi f_m t \cos 2\pi f_s t + N(e) \quad (9)$$

where f_a is the frequency of amplitude variation.

Of course, the foregoing condition also produces randomly distributed periods in which no signal is produced. For no better terminology one might affectionately coin the phase random drop-out to describe this condition. Mathematically this condition can be represented as follows

$$E_{pm}(t) = E^{\circ}(1 + \cos 2\pi f_a t)\cos 2\pi f_m t \cdot \cos 2\pi f_s t + N(e) \qquad t_n < t < t_{n+1}$$
$$= 0 \qquad t_{n+1} < t < t_{n+2} \quad (10)$$

where the $E_{pm}(t) = 0$ periods are randomly distributed in time.

Equation (10) is a fairly accurate representation of the terms that appear in the signal. The physical explanations, however, are overly simplified. For example, the difference in path lengths between the incident and scattered beams contribute to amplitude modulation, intensity variation in the two beams contribute to the noise, the lack of $\hat{E}$ vector alignment (polarization of the beams are not precisely colinear) produces a superimposed, noisy DC component, and an inherent uncertainty in angular alignment produces an inherent uncertainty in the frequency of the Doppler signal. The uncertainty in angular alignment, however, is normally reduced to a negligible value by utilizing an arrangement of apertures and image magnification.

Recognition of the problem at this point is straightforward. One must recover f_s as a continuous function of time. This requires measuring f_s in a signal represented by Equation (10) without the influence of the other terms and holding the last value of f_s measured prior to each drop-out period through that period. Performing this operation electronically is by no means straightforward. Before the readout system was designed a limited number of low-frequence signals for pipe flow were down mixed, recorded on tape and numerically processed in order to help ascertain the distribution of the frequencies f_a, f_m and drop-out for different optical and flow conditions. This information also allowed proof of existence of the desired flow information in the signal. The readout system was designed to essentially reproduce the operations performed numerically. One can also note the conditions represented in Equation (10) by viewing the signal on the oscilloscope in the single-sweep mode on different time scales. Figure 2a is a film of a typical one megahertz signal ($\bar{V}$ = 12 fps) viewed on single sweep using an 0.5 microsecond per centimeter time scale setting and Figure 2b is a film of the same signal using a 50 microsecond per centimeter time scale setting.

One's first tendency is to attempt to measure the time mean flow and the turbulence of intensity with a spectrum analyzer. The spectrum analyzer samples a fixed bandwidth (determined by the resolution) with a center frequency that increases with respect to time at a fixed rate (sweep rate). If the frequencies in the signal correspond to the conditions listed above and if the conditions

contributing to these frequencies are invariant under a translation in time equal to the time interval required to sweep the frequency band in question, the spectrum analyzer will display a normal distribution. In this case the time mean average of the flow is equal to the frequency at which the pulse that appears on the spectrum analyzer is a maximum. The frequency at which the maximum occurs, the most probable frequency and the mean frequency are equal for a normal distribution. Therefore, under the conditions stated above one can obtain mean flow measurements with a spectrum analyzer. However, one must note that flow conditions exist for which the distribution of f_s, f_a, and f_m and various combinations thereof are not normal. Under these conditions one cannot measure mean flow with a spectrum analyzer.

Unfortunately no turbulence information can be obtained with a spectrum analyzer. Since the spectrum analyzer roughly displays the time average of the frequency content of the signal, f_a, f_m and the drop-out frequency appear in the trace. Under normal conditions all of these frequencies fall within or near the frequency band of turbulence. Therefore, the half-level width of the spectrum analyzer trace is approximately the sum of the half-level width of the turbulence distribution, the modulation frequency distribution, the amplitude variation frequency distribution and the band width viewed by the spectrum analyzer. The total half-level width is normally several times

greater than the contribution made by turbulence, so even if all of the extraneous terms could be evaluated and correlated an accurate recovery of turbulence would be next to impossible.

A second and third component can be obtained by repeating the basic components of the one component system.

The Doppler equations for this configuration are readily developed by substituting the appropriate expressions for the multicomponent case into Equation (1). Considering the case illustrated in Figure 2 where

$$V = \hat{i}\, V_x + \hat{j}\, V_y + \hat{k}\, V_z$$

$$K_o = \hat{j}\, K_o$$

$$\hat{K}_s = \hat{i}\, K_{sx} + \hat{j}\, K_{sy} + \hat{k}\, K_{sz}$$

and substituting into Equation (1) one obtains

$$f_D^0 = \frac{n}{\lambda}\left| V_x \sin\theta \sin\psi + V_z \sin\theta \cos\psi + V_y(\cos\theta - 1) \right| \tag{11}$$

$$f_D^0 = \frac{n}{\lambda}\left| -V_x \sin\theta \sin\psi + V_z \sin\theta \cos\psi + V_y(\cos\theta - 1) \right| \tag{12}$$

where $f_D^U \triangleq$ Doppler frequency for the upstream case

$f_D^D \triangleq$ Doppler frequency for the downstream case

For the configuration used to obtain the test data shown herein $\psi = 45^\circ$ and θ was small therefore

$$f_D^U = \frac{n \sin\theta}{\lambda} \left| V_x + V_y - \frac{\theta}{2} V_z \right| \tag{13}$$

$$f_D^D = \frac{n \sin\theta}{\lambda} \left| -V_x + V_y - \frac{\theta}{2} V_z \right| \tag{14}$$

Since θ was small and $V_y < V_z << V_x$ for the flow conditions investigated, the last term was negligible and

$$f_D^U = \frac{n \sin\theta}{\lambda\sqrt{2}} \left| V_x + V_y \right| \tag{15}$$

$$f_D^D = \frac{n \sin\theta}{\lambda\sqrt{2}} \left| -V_x + V_y \right| \tag{16}$$

It is noted at this point that all of the problems that existed in the one component anemometer signal exists in these signals with two additional difficulties. First both scattered beams must be aligned with the incident beam sufficiently close to the same scattering angle θ and the projection of both aligned segments must intersect sufficiently close to the same point to produce the desired accuracy in the correlation of the V_x and V_z components, and this task is much easier to state than to accomplish. Second, the Doppler frequencies must be recovered from the

photomultiplier tubes avoiding the terms discussed in the one component system, with the additional requirement that the voltage to frequency conversions for f_D^U and f_D^D must be accomplished in phase. With the foregoing conditions met, the output of each readout channel is the frequency to voltage conversion of f_D^U and f_D^D on the same time basis

$$V_u(t) = k f_o^U = k \left| V_x(t) + V_z(t) \right| \tag{17}$$

$$V_o(t) = k f_o^D = k \left| -V_x(t) + V_z(t) \right| \tag{18}$$

At this point the output of the two component laser anemometer is on the same basis as a two component hot wire anemometer with the additional ease afforded by having equal weighting of the two components. To obtain $V_x(t)$ and $V_z(t)$, one simply uses a standard correlator to sum and difference V_U and V_D. For the data presented herein a standard correlator and a true RMS meter were used to obtain the values of intensity of turbulence and shear stress.

DEPARTMENT OF CHEMISTRY

ATOMIZATION EFFICIENCY AND QUANTUM EFFICIENCY IN ATOMIC FLUORESCENCE FLAME SPECTROMETRY

Components were assembled into a versatile flame spectrometer system, suitable for research in atomic emission, absorption and fluorescence flame spectrometry. For the construction of electrodeless discharge tube sources, a vacuum system was constructed. Evaluation of the electrodeless discharge tube sources is in progress. Studies of atomic absorption and atomic fluorescence phenomena with these primary sources are continuing. Additional studies of sulfur and phosphorus emission from chilled hydrogen flames are also in progress. These results will be important in water pollution, biological, catalytic poisoning (petroleum), forensic, and many other areas of trace analysis. (by Dr. Claude Veillon, Asst. Prof. Chemistry)

RESEARCH IN QUANTUM SCATTERING THEORY

Research was carried out on a number of problems in scattering theory, with particular emphasis on processes of importance in transfer phenomena in gases and the theory of chemical reactions. The work may be conveniently divided into four general areas of interest.

First we have been concerned with the role of internal degrees of freedom in making possible the formation of meta-stable collision complexes. Both atom-diatom and electron-diatom systems have been studied. It was found that a qualitative and even semi-quantitative description of pressure effects on the low energy drift motion of electrons in molecular gases could be achieved by postulating virtual excitation resonances involving the molecular rotational states. (1). Unfortunately, attempts to make the theory more rigorous have been unsuccessful to date and further research on this subject is planned. The research on compound state resonances in atom-diatom collisions has been extremely fruitful. We have developed very practical methods for calculating resonance energies, widths and shifts. (2). This work is continuing and shows great promise for future computations on various systems of interest. Also, further theoretical research on the problem is underway.

Second, we have succeeded in developing a rapid new method for solving the integral form of the Schrodinger equation for scattering or bound states. The method is applicable for calculating the wave function or for direct computation of the T or R matrices. (3). We have been carrying out a number of test calculations and it appears

the method is capable of both high speed and accuracy. These studies are also continuing and are extremely exciting.

Third we have succeeded in developing a new approach to the calculation of reactive scattering cross sections. This work is closely related to the integral equation techniques which resulted from the research summarized in the above section. It has also been possible to gain new insight into the difficult problem of how to take practical account of the non-orthogonality of initial and final states. (4). This research is also being actively pursued at present and we expect to obtain other very exciting results.

Finally, the fourth area concerns the theory of atom-atom collisions. We have made considerable progress in understanding the manner in which the infinite ranged coupling matrix elements should be treated. A discussion of the H^+-H collision system is presently being written up in collaboration with C. F. Curtiss, and new approaches to the problem have been initiated. This work must still be considered in the formative stage, however, in spite of the progress which has been made. (by Dr. Donald J. Kouri, Asst. Prof. of Chemistry; the references at the end of this report are based in part on work supported under this grant).

RESEARCH IN BORON-NITROGEN CHEMISTRY

A Picker-Nuclear Minimass Mass Spectrometer has been purchased to aid in the investigation of the reaction of lithium nitride with Lewis acids. We have preliminary evidence that the compound $Li_3N \cdot 3BF_3$ is readily formed. Compounds analogous to this one are expected to be precursors to a relatively little studied class of compounds called triborylamines. Triborylamines are of fundamental interest since their structure may be planar or pyramidal depending on the

$$Li_3N \cdot 3BX_3 \xrightarrow{\Delta}_{?} 3LiX + N(BX_2)_3$$

the bonding between nitrogen and boron. If the N-B bond is a simple single bond the structure will be pyramidal like most amines, but if there is active pi bonding between the lone pair of electrons on nitrogen and the empty p orbitals on boron, the structure should be planar. Thus structural studies could reveal valuable information on pi bonding between p orbitals.

A second area of a more applied nature is the study of 1:1 lithium nitride-boron trihalide adducts. It is envisaged that pyrolysis of such compounds could lead to a series of reactive intermediates for the formation of polymeric B-N materials.

Boron-nitrogen compounds show a pronounced tendency toward cyclization such that the intermediates may not be isolatable. Careful thermal analysis may indicate the conditions necessary for intermediate materials to be isolated, however and, if so, these could conceivably be used to prepare new polymeric boron-nitrogen compounds which might have useful properties as special purpose materials. (by Dr. Russell A. Geanangel, Asst. Prof. of Chemistry).

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D. Research in Electrical Engineering

Research participation by the Department of Electrical Engineering in the NASA Multidisciplinary grant has been somewhat sparce. The Department delayed commencement of its activities for one year in order to allow the Mathematics Department more funds during the first year. Since the time of commencement the Department of Electrical Engineering has utilized the funds allocated to help support research projects in a variety of areas. Among these has been research into the problem of light scattering from aerosols. This work has been carried out in conjunction with the Environmental Science Services Administration, the NASA Multidisciplinary grant and departmental funded research. The work has been under the direction of Dr. D. R. Williams and Mr. J. T. Gajjar who is a Ph.D. student in the Department of Electrical Engineering. A complete system including a special purpose computer, optical scattering chamber, an extremely sensitive detector, and an aerosol generation and scavenging scheme has been constructed and data is presently being taken to complete this particular project.

Another project which has received support under this grant was the development of an adaptive character recognition machine. This particular machine was developed and constructed by Mr. William Perry Simonds as the subject of his Master's thesis. Mr. Simonds has received a Master of Science in Electrical Engineering and the character recognition machine is being utilized by the department in conjunction with some other problems and projects in digital systems analysis. This work was under the direction of Dr. James D. Bargainer and was predominantly supported by grants from National Science Foundation with monies from the NASA Multidisciplinary grant being utilized to purchase some special purpose instrumentation and components for the construction of the machine.

One Ph.D. candidate, Mr. John Nemec, was appointed as a Research Assistant on the Multidisciplinary grant during the Fall 1967 semester. During this time he was instrumental in designing and constructing an ultra-stable precision table for helium-neon c.w. laser supports. Additional support in the form of the purchase of equipment and supplies has come from this grant for Mr. Nemec's studies for his Ph.D. dissertation in the area of laser optics. The particular problem now under investigation is the trapping of laser beams in a liquid crystal. This work is under the direction of Dr. William Cook of the Department of Electrical Engineering.

One additional project supported by this particular grant was the construction by several undergraduate students and two graduate students, Mr. Noel Strader and Mr. Gary Summers, of a digital simulator which can be used and is being used to simulate small special purpose computers and digital systems. This system is primarily educational in nature and has been wholly supported from this grant and departmental funds. Many items of equipment, power supplies, components, etc. were purchased in order to construct this system which was designed by Professor James D. Bargainer of the Department of Electrical Engineering.

The majority of the funds supplied by this grant have been used in small amounts to continue or carry out research projects mainly sponsored by the department and the university. These monies have been invaluable in allowing the completion of large numbers of projects which otherwise would not have been completed.

1. Solid State Physics. Dr. Clark Goodman, Professor of Physics

At the time this multidisciplinary grant was initiated, we were fortunate enough to obtain a grant from HEW for lecture demonstration equipment, including Mössbauer apparatus. This equipment, which is used in the introductory physics course for non-science majors called PHYSICS TODAY, has served for the research by several graduate students supported, in part, by Grant NGR-44-005-021:

Charles S. DeJohn - An Investigation of the Absorption and the Diffusion of Gases in Palladium Metal and Zirconium - Iron Alloy using Fluorescent and Mossbauer Techniques Ph.D. Thesis June 1968. This research began with a search for atomic hydrogen in the gas escaping from heated palladium through which hydrogen was diffused. While negative results were obtained, this work provided a foundation for the research on atomic hydrogen in the solar wind which is being supported by a NASA grant through the Manned Spacecraft Center. This study also led to the major investigation: the diffusion of oxygen into alloys of iron and zirconium. The isomer shift, quadrupole interaction and magnetic interaction of the various oxide phases in the alloy made possible the interpretation of complex Mossbauer spectra containing as many as 26-lines. To the best of our knowledge this is the first time such complex spectra have been analyzed by Mossbauer methods. Portions of this research have been published in the abstract and paper listed immediately below. Dr. DeJohn, who is now Research Physicist with Shell Research and Development Corporation, is preparing other papers based on his thesis.
Charles S. DeJohn and Clark Goodman Luminescent Detector of Atomic Hydrogen - Abstract presented at American Physical Society Southwest Section Meetings 1967.
Clark Goodman, C. S. DeJohn, L. D. Lafleur and L. Y. Lee - Applications of Mossbauer Methods, Analytical Instrumentation 6 261-267 (1969). Based on invited paper presented at American Instrument Society Meetings in Philadelphia (1968).

L. Dwynn Lafleur - A Mossbauer Study of Lattice Dynamics in Iron and Iron Salts - Ph.D. Thesis August 1969. Lafleur's research began with a study of iron meteorites using scattering from polished sections. In collaboration with Dr. Elbert King of the Manned Spacecraft Center a paper summarizing these results was published in Science 162 1268-70, 13 Dec. 1968. Subsequently the emphasis was shifted to the more fundamental study of lattice dynamics based on measurements of the Mossbauer fraction f_a and resonant velocity V_o in spectra from metallic iron, sodium nitroprusside, sodium ferrocyanide at several temperatures between 78°K and 293°K.

The observed temperature dependences of f_a and V_o in each absorber were fitted to both Einstein and Debye lattice vibration models. The characteristic temperatures of the models fitted to f_a are consistently lower than those fitted to V_o, showing the sensitivity of the Mossbauer fraction to low-frequency modes of vibration. The characteristic temperatures obtained from V_o are higher for the salts than for the metal, indicating the presence of higher-frequency modes of vibration in the salts. This interpretation is verified semi-quantitatively by comparing the thermal-shift Debye temperatures of the salts to their infrared absorption frequencies. The Mossbauer fraction of potassium ferrocyanide shows a weaker temperature dependence than expected for a harmonic solid. This suggests that potassium ferrocyanide is anharmonic in the temperature range studied. The magnetic field at the Fe^{57} nucleus in metallic Fe and the quadrupole splitting in sodium nitroprusside confirmed earlier measurements by other investigators.

Dr. Lafleur has accepted an appointment as Assistant Professor of Physics at Drury College in Springfield, Missouri. An abstract based on his thesis work has been submitted for presentation at the American Physical Society Meetings in Boulder, Colorado on October 30-31, 1969. A paper is being prepared for publication.

L. Y. (Denny) Lee has been a graduate research assistant under the sustaining grant for the past two years. He has been schooled in Mossbauer methodology by Dwynn Lafleur. About a year ago Denny initiated an experimental study of the resonant scattering of 14.4 kev gammas from magnetized iron. From the outset he observed a small anomaly in the intensities of four of the six lines in the typical hyperfine spectrum. Because the effect is small (a few per cent for lines 1 and 6) it requires 3 to 4 days of continuous observation to obtain statistically significant data. Repeated measurements have convinced us this effect is real. Much effort has been expended in attempting to understand the physical significance of the experiments.

Several theorists have predicted related asymmetries in Mossbauer materials with large mixing ratios (E2/M1) for the gamma ray transitions. Because this ratio is only about 10^{-4} for Fe-57, this commonly used Mossbauer isotope is not suppose to exhibit such asymmetries. A paper was presented at the meetings of the American Physical Society in Boulder, Colorado October 30-31, 1969. Because of the potential relationship between our experimental observations and the very fundamental question of PCT invariance in physical processes, we have invited criticism of our paper from several specialists in this field prior to publication.

In any event the experimental results are certainly challenging and Denny plans to extend this work in his Ph.D. dissertation, scheduled for completion in June 1970.

2. Solid State Physics. Dr. D. C. Rich, Professor of Physics

There is a strong interaction between the electrons in a solid and an acoustic wave when the electrons have a component of velocity in the direction of sound propagation which is equal to the velocity of sound in the material. A calculation is done to estimate the magnitude of the effect this interaction will have on the velocity of sound.

An analysis of the experimental techniques adequate to detect this effect is given, and a description of the experimental apparatus is presented.

During the current contract period, work on the properties of metals has continued using magnetoacoustic techniques. The electronic contribution to the acoustic properties of a medium can be calculated by writing the equation of motion for the medium and solving for the dispersion relation. The basic equation of motion is

$$\rho \frac{d^2\xi_i}{dt^2} = \partial T_{ij}/\partial x_j \qquad (1)$$

where ξ_i is the elastic displacement and T_{ij} is the stress tensor. In the absence of phonon-electron interaction,

$$T_{ij} = C_{ijk\ell}S_{k\ell} \qquad (2)$$

where

$$S_{k\ell} = \frac{\partial \xi_k}{\partial x_\ell} \qquad (3)$$

is the strain tensor. In the simple case of an isotropic medium the dispersion relation is

$$\omega = ks \qquad (4)$$

where

$$s = (c/\rho)^{1/2} \qquad (5)$$

is the velocity of the wave.

Electron-phonon interactions are inserted into the equations by appropriately altering the stress-strain relations, eq. (2). Where the electron-phonon coupling is via a deformation potential, eq. (2) has the form

$$T_{jk} = C_{jk\ell m}S_{\ell m} - \sum_i n_i C^i_{jk} \qquad (6)$$

where C^i_{jk} is the deformation potential tensor for carriers of type i and carrier density n_i.

The equation of motion is then, for a one-dimensional medium,

$$\frac{d^2\xi}{dt^2} = S^2 \frac{d^2\xi}{dx^2} - \sum_i C_i \frac{\partial n_i}{\partial x} \tag{7}$$

This can be solved by noting that $\xi \propto \exp [i(qx-\omega t)]$, where ω, q are the frequency and wave number of the sound wave and by setting

$$n_i = n_i^o + n_i^1 \tag{8}$$

where n_i^o is the density of carriers in the absence of the sound wave and n_i^1 is a perturbation, also assumed proportional to $\exp [i(qx-\omega t)]$. The carrier densities are written in terms of the respective current densities by means of the equations of continuity and the current densities can be related to externally applied electric and magnetic fields by means of constitutive relations derived from manipulation of the Boltzman transport equation. When this complicated process is carried through[2], the desired dispersion relation is obtained for longitudinal waves:

$$\omega^2 = q^2 s^2 \left[1 + \frac{iq^2 (C_e+C_p)^2}{2\rho e^2 \omega s^2} \sigma_{\prime\prime}'\right] \tag{9}$$

where $\sigma_{\prime\prime}'$ is an effective conductivity in the direction of propagation and includes effects of external fields. The velocity of sound is the real part of ω/q; this gives[3] for the normalized charge in s

$$\frac{\Delta s}{s_o} = \frac{q^2 (c_e+c_p)^2}{e^2 s_o^2} \operatorname{Im}(\sigma_{\prime\prime}') \tag{10}$$

Substitution of $\sigma_{\prime\prime}'$ into equation 10 yields

$$\frac{\Delta s}{s_o} = \frac{1}{4} \frac{N_o m}{\rho} \frac{V_f}{s_o}^2 \frac{C_n+C_p}{m v_f^2}^2 (q\ell)^2 \quad X$$

$$\frac{\mu^2 (\omega_c C)^2 + 1/3 (v_f/s_o)^2}{\mu^2 (\omega_c C)^4 + 1/9 (q\ell)^2 (v_f/s_o)^2}$$

where
- ρ = density of material
- s_o = velocity of sound in absence of strong interaction
- N_o = carrier density
- m = effective mass of electron
- v_f = Fermi velocity
- τ = relaxation time of electron in material
- l = mean free path of electron in material
- ω_c = eB/mc = cyclotron frequency of electron in field B

q = sound wave wave number = $2\pi/\lambda$

$= 1 - v_o/s_o$

C_n, C_p = deformation potential of electron, hole.

Inserting values of the parameters appropriate for bismuth gives $s/s_o \sim 10^{-1}$ at $v_D = s_o$, so the effect should be easily observable.

Figure I is a plot of the relative velocity change as a function of v_o/s_o for $X = 0.1$ and $\omega_c\tau = 100$.

During the current reporting period, work has continued on an experiment to measure the velocity of sound of ultrasonic pulses in bismuth single crystals, using the pulse interferometry technique of McSkimin[3], when $V_d \tilde{} V_s$. (V_d is the drift velocity of conduction electrons and V_s is the velocity of sound).

The necessary high drift velocity of the electrons in the sample can be established by imposing mutually perpendicular D.C. electric and magnetic feilds in the sample. To establish the necessary electric field it is necessary to pass large currents through the sample while limiting power dissipation in the crystal to levels which can be tolerated in an experiment performed in liquid helium necessitates pulsing these large currents. A current pulse generator was designed and constructed for this purpose capable of furnishing 45 ampere pulses of duration up to 400 μsec at repetition rates up to 40 pulses/sec. This current capability is also adequate for ultrasonic amplification experiments, which require $V_d >> V_s$.

A block diagram of the assembled equipment is shown in Fig.2. A very stable oscillator (General Radio 1330-A) whose frequency is monitored continuously by a frequency counter, is used as a trigger for the Simpson 2620 pulse generator, the output of which is used to gate the RF generator of the previous section. The trigger output from the Simpson pulse generator is fed into a scalar. The register output from the scalar is converted into a trigger signal for the current pulse generator described previously. In operation the scalar is set to put out a pulse for every 4096 input pulses. This scheme synchronizes the current pulse with the RF pulses applied to the sample, and thereby allows the stable display on an oscilloscope of those RF pulses which are received at the transducer during the current pulse, while rejecting display of those RF pulses which do not occur during the current pulse.

The display on the 545 scope is used to monitor the amplitude of the current pulse by means of a 1/2 ohm resistor in series with the sample.

Macroscopic crystals of bismuth[6] were grown using a Bridgman technique from 99.9999% pure bismuth supplied by Cominco, Inc. Single crystals were produced about 75% of the time by using the soft mole technique[5] with the furnace heater at about 400°C and liquid

nitrogen flowing through the cooling coils. The aluminum oxide powder around the sample allows for the expansion of bismuth upon freezing, and has the additional advantage of preserving the shape of the sample during the growing process; i.e., a single crystal of any reasonably simple shape can be produced by machining the material before placing it in the furnace.

Bismuth crystals grown from the melt show a strong preference for growing with the trigonal axis perpendicular to the growth axis[6]. A total of about fifteen single crystals were grown, of which only three were oriented with the growth axis near the trigonal direction.

An attempt was made to machine the first eleven single crystals grown on a spark planer, but ten of these showed macroscopic recrystallization when etched after planning. The reason for this is not understood, as it proved to be impossible to reproduce the effect outside of the spark machine either by subjecting a single crystal to strain or shock, or by pulsing large currents through a crystal.

To avoid the problem of recrystallization, a grinding apparatus was constructed employing a goniometer crystal mount. The goniometer can be used with an X-ray camera to allow alignment of the sample by Laue back-scattering methods. Two crystals, here labelled A and B, were prepared in the shape of flat rectangles. The dimensions of the two crystals are .467 cm x .852 cm x .917 cm and .402 cm x .861 cm x .962 cm respectively.

Crystal A has x_1 parallel to the trigonal axis, x_2 parallel to the binary axis, and x_3 parallel to the bisectrix. Crystal B was cut with the faces of the sample nearly parallel to the faces of the pseudo-cubic unit ball of bismuth. Use of this orientation complicates the spectrum of the expected velocity change by introducing phonon interactions with electrons of various effective masses, so the $\Delta S/S_o$ curve would have several peaks instead of the single peak of Fig. 1. This effect does not occur for sound propagation in the trigonal direction.

The transducer to crystal bond consisted of a sheet of lens paper soaked in stopcock grease sandwiched between the transducer and crystal. The lens paper was used to provide electrical insulation between the gold plating on the transducer and the crystal; this electrical isolation was necessary to prevent the gold film from shorting the current pulse applied to the crystal, since the conductivity of gold is about fifty times that of bismuth. Electrically isolating the crystal from the transducer also removed the necessity of keeping the crystal grounded, which was an aid in monitoring the amplitude of the current pulse.

The direction of propagation of the sound pulse was along the shortest crystal dimension (along the trigonal axis in the case of crystal A).

The current pulse was introduced into the sample by means of brass electrodes soldered to the crystal with Wood's metal. The electrodes were attached to those faces of the crystal having the smallest area, since this arrangement achieved the highest current density for a fixed total current. In the case of crystal A the applied current pulse was in the bisectrix direction. In each crystal the maximum current density achieved was about 100 amp/cm^2.

Experimental runs were made at 4.2°K in the following way: longitudinal RF wound pulses were introduced into the crystal at intervals of twice the round trip transit time of the sound pulse. The frequency of the sound pulse was near 13 Mc, the resonant frequency of the transducers used. The signal at the transducer was amplified and displayed on an oscilloscope and the pulse repetition rate adjusted for maximum amplitude of the summed reflections. The current pulse amplitude was set at 40 amperes (100 amp/cm^2 in the crystal). The magnetic field was then slowly swept from zero to 50 kg as the RF pulse interference pattern was monitored. Any change in the velocity of sound greater than one part in 10^4 would manifest itself as an observable change in the interference pattern.

No effect could be seen. Since the magnitude of the expected change in velocity when $v_D = S_o$ is about a thousand times greater than the minimum change which could be detected, the necessary conclusion is that a sufficiently high electron drift velocity in the direction of sound propagation was not achieved. This implies a short relaxation time in the sample accuracy. An upper limit for τ can be deduced from the following consideration:

The expression relating the applied current density, J_x, to the current density in the direction of sound propagation, J_y, is

$$J_x = \frac{1}{\omega_c \tau} J_y \tag{12}$$

Now, J_y is given in terms of the drift velocity in the y direction by

$$J_y = ne\bar{v}_y \tag{13}$$

The negative result in the experiment indicates that $v_y < s_o$, so that

$$J_y < neS_o \tag{14}$$

But

$$J_y = \omega_c \tau J_x \quad . \tag{15}$$

so

$$\omega_c \tau J_x < neS_o \tag{16}$$

or

$$C < \frac{neS_o}{\omega_c J_x} \tag{17}$$

using $\omega_c = eB/mc$ this gives

$$\tau < \frac{mncS_o}{B\ J_x} \tag{18}$$

Inserting the values $m = .01\ m_e$, $n = 5 \times 10^{17}\ cm^{-3}$, $S_o = 10^5$ cm/sec, $B = 50$ kg, and $J_x = 100$ amp/cm^2 gives

$$\tau < 10^{-12} \text{ sec.}$$

This is certainly plausible, in view of the large strains which may be induced in the crystal because of differential expansion of bismuth and the brass electrodes during cooling to liquid helium temperatures.

For $\tau = 10^{-12}$ sec, $\tau\omega_c$ is about 10^2 at B = 50 kg; using this in Eq. (4) along with $\Delta S/S_o = 10^{-3}$ and solving (11) for v_D/S_o gives

$$\frac{v_D}{S_o} \sim .99$$

indicating that the above evaluation of an upper limit for τ is not inconsistent with the fact that no change in velocity was seen.

Note: The single experimental difficulty which could be responsible for an ambiguous result was that the thinness of the crystal used resulted in poor differentiation of the individual reflection as viewed on the oscilloscope -- the null areas between reflections were definite but very short. This meant that it was possible that the pattern which was seen was due to electrical interference in the electronics and cables (instead of acoustic interference in the sample). However, any such electrical interference would have been a very sharp function of frequency, and over the (small) range of frequencies at which it was possible to obtain reflections the pattern was found to be independent of frequency.

The preliminary results of this investigation were reported at the Beaumont, Texas meeting of the AAPT, March 16, 1968. The completed work was submitted as a thesis in partial fulfillment and of the requirements for the degree of Master of Science by Nicholas P. Thiessen in August, 1968.

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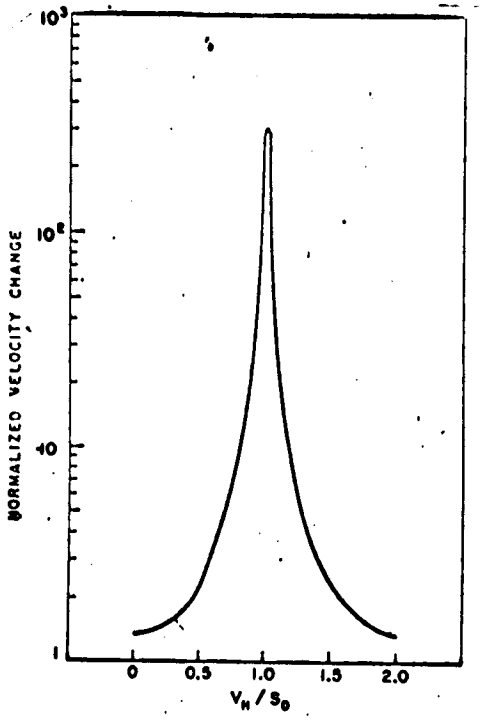

Fig. 1. The normalized change in sound velocity, $(\Delta S/S_o) \times (\rho/N_o m X^2)(S_o/V_f)^2(mV_f^2)/C^2$, shown as a function of v_D/S_o for $X = 0.1$ and $\omega_c \tau = 100$. (From Ref. 4)

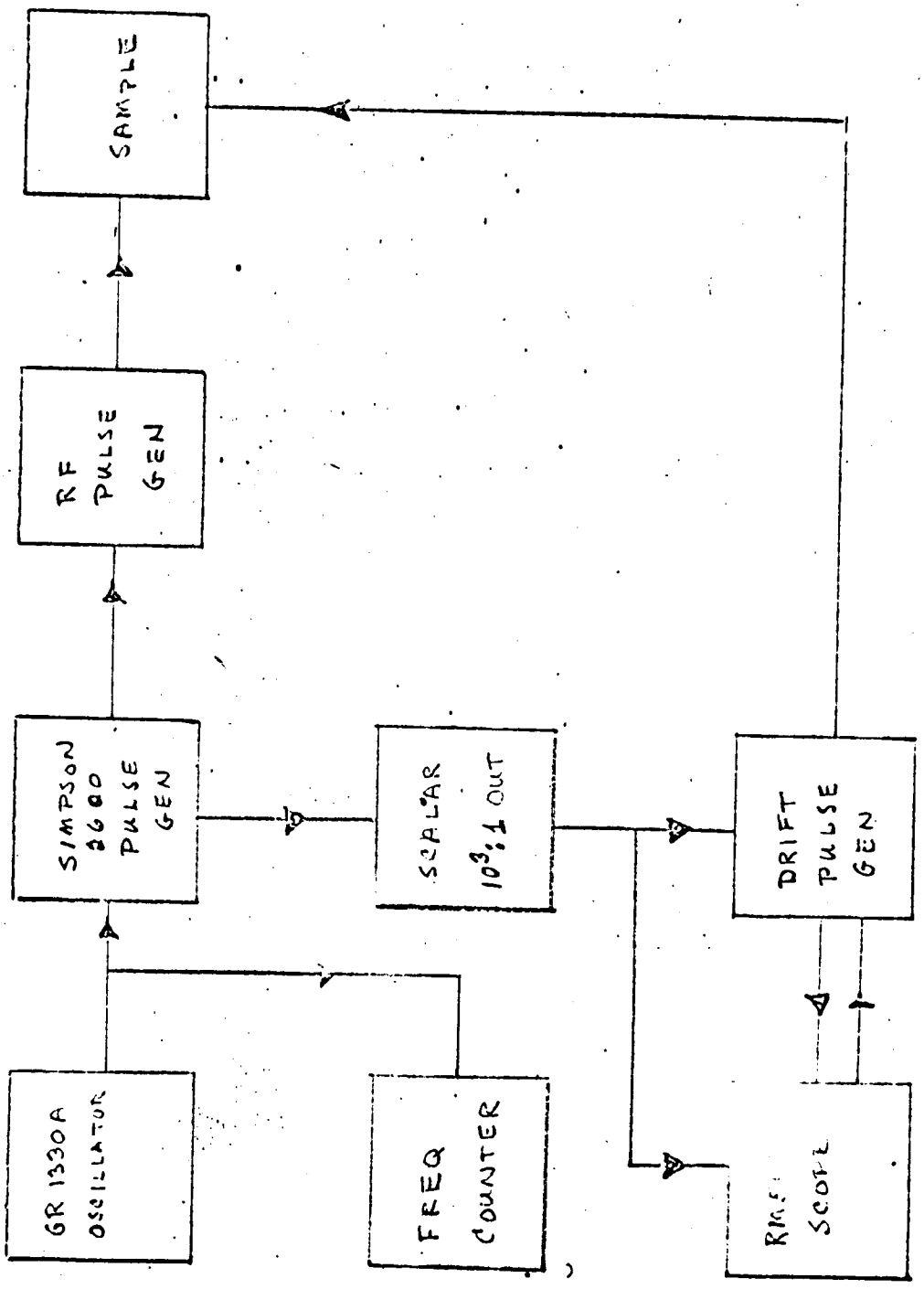

Fig. 2. Block diagram of experimental apparatus.

3. Solid State Physics (Cont'd). Dr. J. B. Coon, Asst. Prof. of Physics

. Band Structure Effects on Electron-Phonon Interactions in Pure Metals and Alloys, J. B. Coon

It is well known that the presence of electrons in metals modifies the form of the phonon dispersion relation[1]. Only in recent years has the actual form of the band structure begun to be incorporated in the study of this effect. The following report details the current progress of a systematic investigation of band structure effects on the phonon spectrum by studying changes in the velocity of sound as a function of changes in the Fermi surface of the material.

It has been shown by Leigh[2] that as the Fermi surface begins to contact a Brillouin zone boundary, the coupling between conduction electrons and phonons becomes unusually large due to redistribution of electrons in bands that are distorted due to the passage of the sound wave. The effect manifests itself in changes in the velocity of sound as well as in the attenuation of the sound wave. If the form of the Fermi surface could be altered in a determined manner, the electron-phonon coupling could be studied as a function of changes in $\varepsilon_F(\vec{p})$ for the electrons by measuring the corresponding shifts in the attenuation and velocity of sound.

Pure thallium, cadmium, or zinc and their dilute alloys are interesting systems in which to initiate this investigation. In each of the metals, theory[3,4] and experiment[5,6,7] indicate that small changes in electron concentration would change the number of regions in which the Fermi surface overlaps a Brillouin zone boundary. The small change in electron concentration can be accomplished by dilute alloying.

The initial experiments are in progress in thallium. The Fermi surface of thallium has been studied using magnetoacoustic effects, the de Haas van Alphen effect, cyclotron resonance, and various d.c. transport measurements.[8] Presently the radio frequency size effect[9] (RFSE) is being employed in this laboratory to gain additional information on the band structure of thallium.[10] The currently available data suggest that the addition of a small amount of donor impurity (approximately .5 atomic percent tin, for example) into pure thallium causes the fourth band electrons to make contact with the zone boundary in the hexagonal direction. The contact would be in the form of thin tubular arms of a very small cross sectional area and cyclotron mass. The appearance of long period dHvA oscillations with H parallel to the hexagonal direction can be used for non-magnetic impurity levels less than approximately .75% to indicate the onset of zone boundary contact. The angular

dependence of the period of the dHvA oscillations indicates the form of the Fermi surface in the contact region. The changes in the attenuation and the velocity of the sound wave as a function of doping is measured and correlated with the Fermi surface data so that the band structure effects can be studied. Theoretical considerations show that an abrupt decrease in the velocity of sound will occur as the Fermi surface becomes connected in the hexagonal direction.

Study of the Fermi Surface of Thallium Using the Radio Frequency Size Effect.

Since precise knowledge of the Fermi surface of pure thallium is necessary for predicting the changes induced by dilute alloying, the RFSE is employed to complete the determination of the Fermi surface in pure thallium metal.[10] This research is in progress at this time under the direction of the author and assigned to James E. Bradfield. Results have been obtained on thallium single crystals for sample thicknesses of .12 mm and .47 mm. Calipers corresponding to extremal orbits on both the major third bank hole surface and fourth band electron surface have been observed. The results are in essential agreement with the ROPW calculation of Soven[11]. Resonances corresponding to previously unobserved orbits have been assigned to non-extremal orbits on the third band electron surface. Evidence of extended orbits on the third and fourth band surfaces due to band degeneracies along the line AL were also seen.

Line shape studies were performed for frequencies between 1.2 and 9.8 Mhz and did not show the characteristic $\omega^{-1/3}$ behavior expected from the anomalous skin effect. Since the line shape is determined by the electric field distribution in the skin depth of the sample, which is in part determined by local scattering mechanisms, this result warrants further investigation. Possible effects of Fermi surface parameters as well as surface scattering mechanisms will be considered.

Signals were observed at magnetic fields corresponding to integral multiples of the first order RFSE resonance value. These "field splashes"[9] have been observed by other investigators in different pure metal crystals. A detailed study of the line shape, however, has not been accomplished.

This research is being continued as part of the alloy research program. Of particular importance is the accurate determination of the "hornlike" protrusions of the fourth band electron surface near the point H in the Brillouin zone. It is this portion of the Fermi surface that will participate in the overlap connection. The energy gap at this point as well as the separation distance between the fourth band electrons and the ΓMK plane may be determined by the calipers obtained from an orbit such as E'- E' in

Figure 4 of Reference 5. Note that the calipers must be taken on the orbit in regions of high curvature. The R.F.S.E. is inherently better suited to this determination than other techniques such as geometric resonances. It is also of interest to caliper the third band along the [1010] direction. Since the third and fourth bands are degenerate and touch along the line A-L, this point should serve as a good reference point for setting the Fermi level for theoretical calculations.

Determination of the Velocity Shifts in the Dilute Thallium-Tin Alloy System.

Measurement of the velocity shifts due to changes in the band structure in the alloy system are in progress and assigned to Ronald M. Crews. Although a complete interpretation of the data is dependent upon information gained in the RFSE experiment, we expect to be able to accumulate enough data to begin initial interpretation by June 1970. Sufficient information from the RFSE experiment will be available to allow the study to be completed by the spring of 1971.

Experiments indicate that changes in the velocity of sound over the proposed range of alloy compositions should be on the order of one to five percent. Thus precise measurements of the absolute velocity of sound are necessary. A variation of the McSkimin[12] pulse superposition technique developed by Papadakis[13] is used for this investigation. Capabilities for absolute measurements of the velocity of sound are approximately .05%. The apparatus has been improved and assembled in our laboratory.

Attenuation measurements of the series of samples will also be performed. Losses from sources other than the normal electrons can be subtracted from the total sonic attenuation by measuring the attenuation in the normal and superconducting state of pure thallium and in the alloys. Since $\alpha_{normal} = \alpha_{apparent} - \alpha_{superconducting}$ to a very good approximation at liquid helium temperatures, meaningful comparisons of the attenuation due to the normal electrons can be made between samples.

Growth of large single crystals of tin doped thallium has been accomplished despite difficulties incurred due to a solid state phase transition. Construction of a spark erosion crystal slicing and planing apparatus[14] has been completed complementing the available crystal preparation facility.

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4. Astro-Physics Research. Dr. J. W. Kern, Associate Professor of Physics

Astro-Physics Research under Dr. Kern is best summarized by the theses and publications which have resulted:

1. Effects of Anomalous Resistivity in the Magnetosphere
2. Evidence for Impulsive Particle Precipitation at Middle Latitudes
3. X-Ray Pulsation Observations at Midlatitude
4. Hydromagnetic Wave Propagation in the Earth's Magnetosphere
5. Transit-Time Heating of Particles in the Magnetosphere
6. Effects of Hydromagnetic Waves in the Magnetosphere

EFFECTS OF ANOMALOUS RESISTIVITY IN THE MAGNETOSPHERE *

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Recent observations suggest that neutral line models for driving ionospheric convection are necessarily less effective than previously proposed. More comprehensive observation of ionospheric currents are presently available than those used to construct existing phenomenological models of magnetospheric dynamics. Taken together with recent observations of electric fields in auroral arcs and barium releases at high latitudes, these data suggest substanital revision of existing models is required. The present paper discusses the consequences of anomalous resistivity for dynamical theories of the magnetosphere. The origin of the anomalous resistivity is in wave-particle interactions, the waves being internally generated as a result of dynamical (two-stream) instabilities. The principle effects of anomalous resistivity are in (a) sustaining potential differences along magnetic field lines in regions of field-aligned currents, and (b) increasing the height-integrated direct (Pedersen) conductivity connected with polar-ionospheric currents. The first is important in relation to the precipitation of low energy electrons and protons in the auroral belt. The second effect (to our knowledge, first introduced here) has important consequences for the distribution of currents observed in the ionosphere for any dynamical model of the magnetosphere. The relations of field-aligned currents to regions of anomalous resistivity are analyzed in connection with the observed morphologies of ionospheric currents, auroral precipitation, and electrostatic wave observations in the magnetosphere.

It is found that the primary effect on the analysis of ionospheric currents is to increase the height-integrated Pedersen conductivity. Field-aligned currents can however appear as a result of anomalous resistivity in regions conjugate to the auroral belt; not all of the current closure for steadystate models need be in the ionosphere. The result is that even purely inductive mechanisms for driving convection in the magnetosphere will generate field-aligned currents. The change in scale lengths of electric potential distributions parallel and transverse to the magnetic field can be evaluated. It is found that thin auroral arcs cannot be purely electrostatic phenomena originating at large distances along field lines if appreciable internal wave excitation is present. Large scale features of ionospheric currents and particle precipitation patterns can however be rationalized in a theory incorporating significant wave-particle interactions.

EVIDENCE FOR IMPULSIVE PARTICLE PRECIPITATION AT MIDDLE LATITUDES *

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J. W. Kern, Dept. of Physics, University of Houston, Houston, Texas

A measurement of the X-ray intensity at a residual atomspheric depth of 8 gm/cm^2 was made on June 25, 1964, from a balloon in the vicinity of Seattle, Washington (L = 2.7). X-rays at four integral energies (>20 KeV, > 50 KeV, > 100 KeV and > 200 KeV) were measured with an unshielded NaI crystal. The resulting energy spectrum at altitude and the counting rate curves during the ascent to altitude are shown to be in good agreement with the results of other workers. However, analysis of the high-altitude counting rate with fast time resolution reveals the existence of microbursts similar to those which have been measured in the auroral Zone. These measurements of X-rays in the atmosphere are compared to the precipitation of energetic trapped electrons which has been observed from satellites in the same region of L values. The role of wave-particle interactions and instabilities in the precipitation of trapped particles from both the inner and outer belts is discussed.

* International Association of Geomagnetism and Aeronomy Program and Abstracts for the Gerneral Scientific Assembly, Madrid, September 1-12, 1969

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X-Ray Pulsation Observations at Midlatitude.* Balloon observations of x-ray pulsations at a residual atmosphere depth of 8 gm cm^{-2} reveal a new phenomena of suddenly shifting periodicities in the range 0.25 to 1 sec for x-rays >20 kev. Modulation of the count rate by a factor of 50% is observed during shorter-period modulation events. The pulsations occurred inside the plasmapause at L = 2.7 during a geomagnetically quiet period. Simultaneous surface magnetometer observations are discussed. Current theories of auroral zone x-ray pulsations are examined and an explanation is proposed in terms of ion-acoustic oscillations of an energetic plasma near the equatorial plane.

* EOS Transactions American Geophysical Union
Vol. 50, No. 11, November 1969

HYDROMAGNETIC WAVE PROPAGATION IN THE EARTH'S MAGNETOSPHERE*

ABSTRACT

Under the restrictions of the geometrical optics approximation, optical ray paths and the intensity of a wave front as a function of the ray paths have been calculated for high frequency hydromagnetic waves propagating in a simple model of the earth's magnetosphere. Because of the bending of the rays in a nonhomogeneous isotropic medium, the waves are found to be deflected as they travel inward toward the earth. The envelope through which no rays penetrate is found to be a function of the density of the medium and the geomagnetic dipole field of the earth.

The intensity of a wave as a function of the ray path is also calculated and is shown to fall uniformly from its value at the boundary of the magnetosphere as the wave front propagates inward. Contours of equal intensity are drawn for the sunward side of the earth and found to be approximately similar in shape to the boundary of the magnetosphere.

* A Thesis Presented to the Faculty of the Department of Physics University of Houston by Daniel Edward Gibbons, January, 1967

John W. Kern, Daniel E. Gibbons (Univ. of Houston, Houston, Tex.), Transit-Time Heating of Particles in the Magnetosphere.* Local particle heating by hydromagnetic waves is calculated as a function of geocentric distance in the magnetosphere. The waves considered are the fast magnetosonic mode of hydromagnetic waves. They interact with particles through the coupling between the magnetic movements of the trapped particles and the magnetic field perturbations of the waves; this interaction leads to the so-called transittime damping of the waves. The energy per unit volume per unit time given to both thermal and nonthermal particles is calculated, using recent data for the characteristics of the particles. It is found that thermal protons acquire little energy but that the power transferred to thermal electrons is significant, both for quiet and disturbed times. The power absorbed by nonthermal proton fluxes is also found to be significant, with maximum local heating at 3-4 R_E. The total power input to thermal electrons by a wave of 10^{-4} gauss amplitude is found to be $\sim 10^{19}$ ergs per wave period beyond 5 R_E. Nonthermal proton fluxes absorb $\sim 10^{20}$ ergs per wave period inside of 4 R_E. The power inputs are large enough to account for the requirements of high latitude phenomena and for ring current heating.

* TRANSACTIONS, AGU - Vol. 49, No. 1, March 1968

EFFECTS OF HYDROMAGNETIC WAVES IN THE MAGNETOSPHERE*

ABSTRACT

The effects on the plasma trapped in the earth's magnetosphere by hydromagnetic waves propagating in the magnetosonic mode are considered in this paper. First, local particle heating due to an energy exchange between particles and waves known as magnetic Landau (transit-time) damping is investigated. Heating of both thermal particles and proton fluxes is considered. While thermal protons receive little energy from such a mechanism, a large quantity of energy of the order of 10^{16} to 10^{18} ergs per sec within a volume of 10 earth radii can be supplied to the thermal electrons. The heating of nonthermal, fast proton fluxes is also calculated and are found to receive by magnetic Landau damping an energy per unit volume which is two orders of magnitude higher than the heating for thermal electrons. The proton fluxes, however receive a power input two orders of magnitude higher than the thermal electrons. The energy input to the protons is found to be able to penetrate deeply into the magnetosphere and to be sufficient to sustain a diamagnetic ring current which is believed to be responsible for large geomagnetic storms.

The exchange of momentum between the waves and particles is considered in the second part of the paper. By not discarding the imaginary part of Maxwell's equations in reduced form, the eikonal equation is shown to be true for

* A Dissertation Presented to the Faculty of the Committee of Physics University of Houston by Daniel Edward Gibbons January 1969

all frequencies and wavelengths. A divergenceless wave momentum density is constructed from which a radiation pressure tensor is formed. This tensor is then added to the magnetic field tensor and kinetic pressure tensor in the magnetosphere in order to calculate the effect on the earth's magnetic field. It is found that the field at the earth will vary by several gamma ($1\,\gamma = 10^{-5}$ gauss) in magnitude due to the exchange of momentum between particles and hydromagnetic waves.

CONCLUSION

Hydromagnetic waves propagating from the instabilities of the magnetopause have been shown in the preceding analysis to be a possible source of local heating for the magnetosphere. No mechanism to date has been suggested by other investigators which could explain the energy input needed for the observed increase in particle pressures and energies during disturbed conditions on the earth. Also, any acceleration of particles must occur deep inside the magnetosphere, and at all points. Waves of the HM variety could be the source of power needed for transfer of energy between the solar wind and the region inside the earth's magnetosphere.

As has been shown the macroscopic pressure due to wave-particle momentum exchange, while small, can be observed at the earth's surface and must be taken into account when equating particle and magnetic field pressures for equilibrium conditions. Localenergy exchange is provided by the magnetic field vector of the waves and a typical energy of 10^{15} to 10^{21} ergs per sec can be injected into the particles depending upon wave amplitude. This is the energy requirement for the geomagnetic ring current needed to explain large magnetic storms observed at the earth's surface.

The time variation of the energy distribution in the

outer zone, $3R_e \leq r \leq 10R_e$, during high K_p values can be interpreted as resulting from transit-time damping since the greatest heating occurs in this region. Further, while the proton fluxes contain the greatest amount of energy, the difference in thermal electron and proton tempreatures in this region can result from waves since a value of T_i two orders of magnitude lower than T_e is predicted. The waves even though highly damped in the outer region can penetrate to approximately $L \approx 10$ to $12\,R_e$ for both proton flux and thermal electron damping. Thus, heating can occur at all points inside the magnetosphere at about the same time.

Upon considering equilibrium conditions between the wave-particle enery densities, a large number of particles will achieve energies equal to the wave energies. Two peaks occur for this condition which correspond roughly to the peaks for the inner and outer Van Allen radiation belts. The ratio of particle density to magnetic field density can be greater than unity during magnetic storms in the outer region and this seems to fit the observed data.

Of course, the model presented here is a very simplified one. First, only a single frequency propagating throughout the volume of the magnetosphere is used. A more complete analysis could determine the heating effects of a realistic power spectrum for the waves. Second, the

magnetic field of the earth is considered to be a dipole and a more sophisticated field geometry could be used. Third, the particle densities and waves are considered to be radially symmetric which is, of course, not the observed case. These restrictions do not appear to be fundamental, however. Therefore, we conclude that heating by wave-particle interactions can be an effective method of acceleration of particles in the magnetosphere and providing the mechanisms for generating geomagnetic storm ring currents and particle energy variations.

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MODEL FOR COMET-SOLAR WIND INTERACTION

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Abstract—The size and shape of the contact discontinuity around a comet's nucleus are found based on the assumption that the ions moving away from the nucleus are non-interacting and that these ions are specularly reflected by the solar wind's frozen-in magnetic field. By superimposing the density due to the ions flowing directly from the nucleus and the specularly reflected ions, contours of constant density inside the cavity are obtained. It is found that the calculated size and shape of the cavity agree with observational data and that certain of the anomolous plasma formations (clouds, rays) found in type I tails may be explainable by the model.

1. INTRODUCTION

Much of the most recent work in the area of cometary physics has been aimed at analytically solving the problem of the solar wind flow past a comet (Ioffe, 1966; Kovar and Kern, 1966; Biermann, Brosowski and Schmidt, 1967). The general approach in these treatments is that of gas dynamics. Continuity of the solar wind flow is effected by its frozen-in magnetic field. The fact that the solar wind moves at supersonic velocity has led many authors to postulate the formation of a shock upstream from the comet (Alfvén, 1957; Marcochnik, 1963; Axford, 1964; Ioffe, 1966). A particular difficulty in solving the flow problem is the modification of the hydrodynamic equations to include source terms. Molecules sublimated from the nucleus become ionized and eventually load the solar flow. Still another difficulty is that the plasmas considered are compressible.

A distinguishing feature of the comet-solar wind interaction is the formation of a contact discontinuity which separates purely cometary material from solar wind material. This surface acts like a blunt object in that the solar wind is forced to flow around it. The flow, then, is somewhat analogous to that of the solar wind past the Earth, for here also a shock front and a contact discontinuity result.

Section 2 presents the model investigated. The two major assumptions are discussed in detail. These are: (1) there is no magnetic field interior to the interface separating cometary material from the solar wind, (2) the ions moving away from the comet's nucleus are specularly reflected from this interface. An analytic expression for the density of the outflowing ions is also obtained in this section.

The size and shape of the contact discontinuity are found in Section 3. The solutions are in terms of familiar functions for two limiting cases, but in the general case, due to the non-linear nature of the differential equation involved, solutions were obtained numerically. The parameters determining the scaling of the cavity are discussed and appropriate values are adopted for them.

Section 4 contains the formal solution for the density contours inside the contact discontinuity. A unique feature of the ion density in this region is a discontinuous jump across a boundary termed the caustic. This curve is investigated in detail. Higher order reflections are also discussed in this section and are found to be insignificant.

Correlations between the model and observational data are noted in Section 5. It is found that the predicted ion density and the size and shape of the cavity agree well with

observational data. Other correlations, especially those of a time dependent nature, are suggested by the model but are not considered to be conclusive.

Section 6 summarizes and concludes the paper.

2. THE PROPOSED MODEL

The purpose of the model investigated here is to find the size and shape of the contact discontinuity around a comet's nucleus and the density of plasma interior to it. Several assumptions are made in the process of developing the model. Two are of sufficient importance to warrant detailed discussion, namely, that there is no magnetic field inside the contact discontinuity and that ions flowing from the nucleus are specularly reflected from this interface.

In previous treatments, the plasma flowing away from the comet's nucleus has been regarded as a continuous medium. Since the mean free path for collision of ions is very long ($\sim 10^5$ km), this assumption is questionable. To support this approach the argument has been made that magnetic fields present in the comet's coma would provide continuity in the flow. However, it is to be noted that, since the outflowing plasma is diamagnetic, it is highly likely that the region interior to the contact discontinuity will be devoid of a magnetic field.

If one accepts the existence of a contact discontinuity and also that the solar wind's magnetic field is frozen-in, then obviously no magnetic field can penetrate the cavity since the field will be carried by as the solar wind flows past. However, several authors (Alfvén, 1957; Marochnik, 1963) have speculated that the magnetic field carried by the solar wind may become partially trapped in the cometary plasma between the shock and the contact discontinuity. The problem then is to find the length of time it will take this field to diffuse into the plasma inside the cavity. A problem closely related to this one has been considered by Piddington (1959). He has calculated the time required for the Earth's magnetic field to relax (through outward diffusion) after being compressed by the solar wind; he finds a relaxation time of about 18 yr. The problem to be treated here is the inverse of the one considered by Piddington, i.e., in this case the magnetic field is diffusing from the solar wind rather than into it. An approximate value for the time, τ, required for the solar wind's field to diffuse into the cavity is given by $\tau = \pi\sigma R_0$, where R_0 is the radius of the cavity and σ is the conductivity of the plasma inside the cavity. Setting $\sigma = 10^{-14} T^{3/2}$, and with $T = 600°\text{K}$ and $R_0 = 10^9$ cm, a value of $\tau = 10$ yr is obtained.

With no magnetic field present, it can be assumed that the outflowing ions move independently of one another. When the ions reach the boundary, the pressure they exert is just sufficient to balance the pressure of the solar wind. Exterior to the boundary, where magnetic fields are present, a continuous flow will exist. Assuming the solar wind's frozen-in field to have a direction perpendicular to its flow direction, the magnetic field configuration will be one of concentric circles around the contract discontinuity. The outflowing ions will be deflected by this field back into the cavity. Assuming that energy and momentum are conserved, the ions will be specularly reflected from this boundary, i.e., their angle of incidence and reflection, with respect to a unit normal to the surface, will be equal.

Using these assumptions, the size and shape of the contact discontinuity and the ion density interior to it will be determined. The size and shape are treated in the following section and the ion density in Section 4. The solution of both problems depends upon the density of outflowing ions, which is now considered.

Inside the contact discontinuity only photoionization can be effective in converting the

outflowing neutrals into ions. This simplifies the problem considerably. The nucleus is here treated as an isotropic point source of neutral molecules and the assumption is made that as the neutrals are ionized their velocity is unchanged. The net outflow of material, i.e., neutrals plus ions, is thus governed by the equation $\nabla \cdot (\rho^* \bar{v}) = S\delta(\bar{r})$, where ρ^* is the total density, $\bar{v}$ the average ejection velocity of neutrals from the comet's nucleus, S the mass production rate, and $\delta(\bar{r})$ the Dirac delta function. This equation can be integrated to give.

$$\rho^* = (S/4\pi v)(1/r^2). \tag{1}$$

Since the neutrals are being ionized with time constant τ, the density of neutrals, ρ_n, is determined by $\nabla.(\rho_n \bar{v}) = -\rho_n/\tau$. Integration of this equation gives

$$\rho_n = (S/4\pi v) \exp(-r/v\tau)/r^2. \tag{2}$$

Subtracting (2) from (1) then gives for ρ_0, the ion density

$$\rho_0 = (S/4\pi v)[1 - \exp(-r/v\tau)]/r^2. \tag{3}$$

3. THE CONTACT DISCONTINUITY

Following the procedure used by Beard (1960) and others, an analytic expression for the contact discontinuity can be obtained by balancing solar wind pressure and the pressure exerted by the outflowing ions. On the sufrace where the pressures balance

$$\rho_s(\bar{v}_s \cdot \bar{n})^2 = \rho_0(\bar{v} \cdot \bar{n})^2. \tag{4}$$

The s subscripts refer to the solar wind and $\bar{n}$ is a unit normal pointing in the outward direction. The $B^2/8\pi$ contribution to the solar wind pressure is neglected in this equation since it is an order of magnitude less than the kinetic pressure. The geometry involved is shown in Fig. 1. Let $\bar{e}_r$ and $\bar{e}_\theta$ denote unit vectors parallel and perpendicular to the radial direction. Then the following relationships hold:

$$\bar{v}_s/v_s = -\cos\phi\bar{e}_r + \sin\phi\bar{e}_\theta$$

$$\bar{v}/v = \bar{e}_r$$

$$\bar{n} = [\bar{e}_r - (1/R)(\mathrm{d}R/\mathrm{d}\phi)\bar{e}_\theta]/\sqrt{(1 + [(1/R)(\mathrm{d}R/\mathrm{d}\phi)]^2)}.$$

Substituting these and Equation (3) into Equation (4) gives

$$\sin\phi\,\mathrm{d}R/\mathrm{d}\phi + R\cos\phi = \sqrt{(Sv/(4\pi\rho_s v_s^2))}\,\sqrt{(1 - \exp(-R/v\tau))}. \tag{5}$$

Note that as $\phi \to 0$ Equation (5) gives an expression for R_0, the on-axis distance where the pressures balance, i.e.,

$$R_0 = \sqrt{(Sv/(4\pi\rho_s v_s^2))}\,\sqrt{(1 - \exp(-R_0/v\tau))}. \tag{6}$$

Hence, Equation (5) can be written

$$\sin\phi\,\mathrm{d}R/\mathrm{d}\phi + R\cos\phi = \sqrt{(1 - \exp(-\beta R))}/\sqrt{(1 - \exp(-\beta))}. \tag{7}$$

This is the basic equation determining the form of the contact discontinuity. R_0 has been set equal to unity with the understanding that it is the unit for measuring distance. The parameter β is defined by $\beta = R_0/v\tau$.

Unfortunately, Equation (7) is non-linear and appears to have no solution in terms of

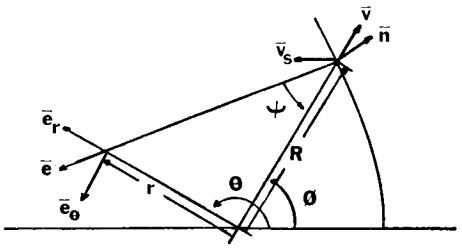

FIG. 1. GEOMETRY INVOLVED IN PRESSURE BALANCE AND REFLECTION PROCESS.

familiar functions. However, for the special cases of $\beta \ll 1$ and $\beta \gg 1$, Equation (7) reduces to, respectively,

$$\sin\phi\, dR/d\phi + R\cos\phi = \sqrt{(R)}$$

and

$$\sin\phi\, dR/d\phi + R\cos\phi = 1.$$

Both of these equations are soluble in terms of familiar functions. The solutions, in order, are

$$R = 2F^2(Q)/\sin\phi$$

and

$$R = \phi/\sin\phi$$

where F is Legendre's elliptic integral of the first kind having modulus $\sqrt{(2)}/2$ and Q is given by:

$$Q = \tan^{-1}\sqrt{([2\tan(\phi/4)]/[1-\tan(\phi/4)])}$$

(Byrd and Friedman, 1954, p. 710).

For the general case, where approximations to the exponential term in Equation (7) cannot be made, numerical methods must be employed. In rectangular co-ordinates the equation to be solved is

$$dy/dx = y/\{x - (x^2+y^2)\sqrt{([1-\exp(-\beta)]/[1-\exp(-\beta\sqrt{[x^2+y^2]})])}\}. \qquad (8)$$

In the range $0{\cdot}01 < \beta < 1$, the two limiting cases fail. Values of β in this range were thus chosen and this equation was integrated using the Runge–Kutta method.

Figure 2 shows plots of the contact discontinuities for the two limiting cases. These curves represent boundaries within which curves in the intermediate range of $\beta(0 < \beta < \infty)$ must lie. If R is regarded as a function of both ϕ and β, then as β varies from 0 to ∞, all possible contact discontinuities are generated; effectively, the curve defined by $R = 2F^2/\sin\phi$ is rotated into $R = \phi/\sin\phi$. As can be seen from Fig. 2, the shape of the contact discontinuity is relatively insensitive to the value of β. In this figure, for comparison purposes, a plot of the surface $R = \sec(\phi/2)$ is included. This contour is the continuation of the on-axis streamline (for the case of potential flow) of a uniform flux from infinity past an isotropic point source. Inclusion of the parabola and catenary in this figure will be explained in Section 5.

The size of the cavity can be determined as follows. Equation (6) for the on-axis stopping distance of the solar wind can be written $\beta^2 = \alpha[1-\exp(-\beta)]$, where $\alpha = Nm_n/(4\pi\rho_s v_s^2 v\tau^2)$. Here $S = Nm_n$, where N is the number of neutrals of mass m_n produced per second. If α is specified, then β is determined. Once β is fixed, the cross-section of the cavity at ∞, R_π, is determined. Thus, the parameter α determines the scaling of the cavity.

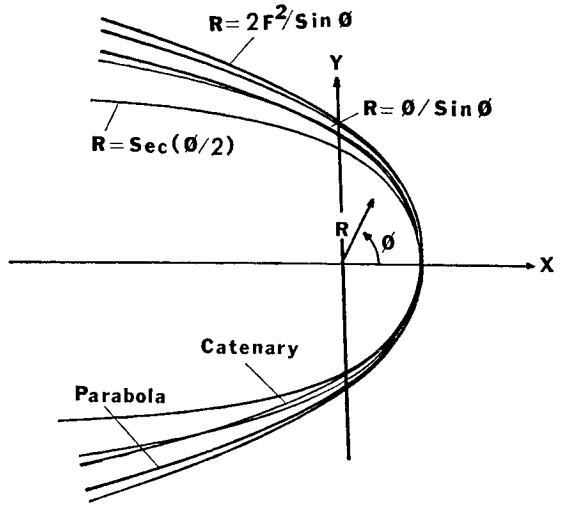

FIG. 2. THE CONTACT DISCONTINUITIES.

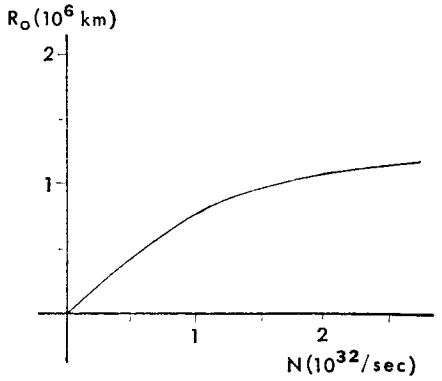

FIG. 3. STOPPING DISTANCE AS A FUNCTION OF PRODUCTION RATE OF NEUTRALS.

Now $R_0 = v\tau\beta$ and $N = [(4\pi\rho_s v_s^2\tau^2)/m_n]\alpha$; hence, by adjusting the $\beta - \alpha$ scales, the $\beta = \beta(\alpha)$ curve also represents $R_0 = R_0(N)$, i.e. the stopping distance as a function of the number of neutrals produced per second. To determine the scale factors, values must be assigned to the constants involved. The more abundant neutral molecules include CN, C_2, CO, and N_2. These all have molecular masses of $\sim 30\, m_p$, where m_p is the mass of a proton. The time constant for ionization is a more uncertain quantity. Its value will depend on the molecular type. Thus τ should be regarded as an average. $\tau = 10^6$ sec is adopted here. The ejection velocity $v = 10^5$ cm/sec has been chosen (Wurm, 1963). Values of ρ_s and v_s are those corresponding to a distance of 1 a.u., i.e. $\rho_s = m_p/\text{cm}^3$ and $v_s = 500$ km/sec. With these values, then, $R_0 = 10^6\beta$ km and $N = 10^{32}\alpha$/sec. Figure 3 shows a plot of $R_0 = R_0(N)$ in the range of most rapid change.

For the limiting case $\beta \gg 1$ the cross-section of the cavity at infinity, R_π, is given by $R_\pi = \pi R_0$, while if $\beta \ll 1$, $R_\pi = 2K^2 R_0 \approx 6{\cdot}68\, R_0$, where K is Legendre's complete elliptic integral of the first kind with modulus $\sqrt{(2)}/2$. Note that the ratio R_π/R_0 effectively doubles from one limiting case to the next. This is to be expected since in the case where

$\beta \gg 1$ the ion density falls off as $1/r^2$ whereas in the other limiting case, $\beta \ll 1$, the fall off is weaker, i.e., $\rho_0 \propto 1/r$.

4. THE ION DENSITY IN THE COMA AND TAIL

The problem of finding the density of ions inside the cavity is now considered. At present, only part of the density is known, viz. the density due to ionization of the outflowing neutrals. However, in the discussion in Section 2, the assumption was made that the outflowing ions were specularly reflected from the interior of the cavity's boundary. Hence, to find the total density, the contribution from not only the outflowing ions but also the reflected ions must be considered. Note that, formally, the reflection process can continue indefinitely. For the moment, only the density contribution from ions which have been once reflected will be considered. The problem of higher order reflections will be treated later.

The density of ions due to first reflections can be found as follows. Consider that portion of the contour reached only by ions flowing directly from the nucleus as an ion source. Let ions be emitted in a direction such that the inner normal to the surface of the cavity bisects the angle between unit vectors pointing toward the nucleus and along the emission direction. Let the intensity of the source be

$$\rho_0(R) = S/(4\pi v)[1 - \exp(-R/v\tau)]/R^2.$$

By superposing the density due to this 'line source' and the density due to ions flowing directly from the nucleus, the net density is obtained. The geometry involved in the reflection process is shown in Fig. 1.

The ion flux, $\rho_1 \bar{v}$, from the line source must satisfy $\nabla \cdot (\rho_1 \bar{v}) = 0$, subject to the boundary condition that $\rho_1(R) = \rho_0(R)$. Integration gives

$$\rho_1 = \rho_0(R) R \sin \phi/(r \sin \theta) \tag{9}$$

Thus far, it has been assumed that reflected ions from only one surface point can reach a given point inside the cavity. However, in general, this condition need not hold. To include the possibility of reflected ions from more than one surface point reaching a given r, θ the reflected density must be summed. The total density, ρ, is then given by

$$\rho = \rho_0(r) + \sum_{j=1}^{m} \rho_0(R_j) R_j \sin \phi_j/(r \sin \theta)$$

where R_j, ϕ_j is the j^{th} set of values such that reflected ions from this point on the surface can reach a given r, θ and m is the total number of pairs. Expanding the expression for ρ using (3) gives

$$\rho = (1/r^2)\{[1 - \exp(-\beta r)]/[1 - \exp(-\beta)]\} + \sum \{[1 - \exp(-\beta R_j)]/[1 - \exp(-\beta)]\} \sin \phi_j/(R_j r \sin \theta)$$

where the unit of density is $\rho_0(R_0)$. For the limiting cases of interest here, $\beta \ll 1$ and $\beta \gg 1$, this solution reduces to, respectively,

$$\rho = 1/r + \sum \sin \phi_j/(r \sin \theta) \tag{10}$$

and

$$\rho = 1/r^2 + \sum \sin \phi_j/(R_j r \sin \theta). \tag{11}$$

Note that each ϕ must satisfy

$$r \sin(\theta - \phi + \psi) = R \sin \psi. \tag{12}$$

Now, since $\psi = 2 \tan^{-1} (1/R \, dR/d\phi)$, once $R = R(\phi)$ is specified and a point r, θ chosen, Equation (12) determines a unique set of ϕ's from which the density can be determined.

Perhaps the clearest way of showing qualitatively how the number of roots of Equation (12) depends on the particular r, θ chosen is graphically. For $\theta = \pi$, this equation reduces to

$$R_c = R \sin \psi / \sin (\phi - \psi)$$

where R_c is the distance at which ions from R, ϕ cross the axis. This equation is sufficient to determine the qualitative behaviour of m. If values are now chosen for ϕ, a set of trajectories for the reflected ions is obtained. This set of trajectories for the surface $R = \sec (\phi/2)$ is shown in Fig. 4. Inspection of this figure indicates that a boundary exists which separates regions where $m = 1$ and $m = 3$.

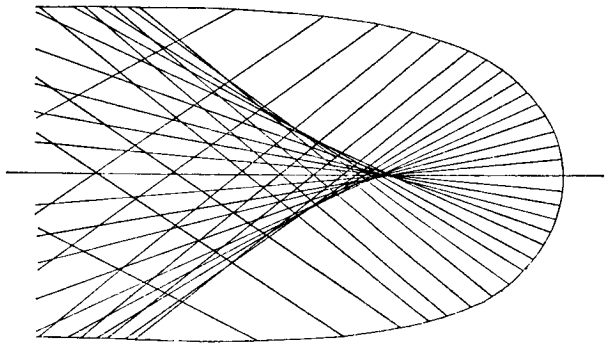

FIG. 4. THE ION TRAJECTORIES.

The problem of finding an analytic solution for the boundary is analogous to the optical problem of finding the curve enveloping light rays emanating from a point source and reflected from a curved mirror. Hence, this boundary will be referred to as the caustic. Let s be the distance from the surface along an ion path to the caustic and r^*, θ^* the coordinates of the point the trajectory and the caustic have in common. Using the notation of Fig. 1, the distance s is given by

$$1/s + 1/R = 2k \cos (\psi/2) \tag{13}$$

(Brand, 1947, p. 104). Here $k = k(\phi)$ is the curvature of the contact discontinuity which is given by

$$k = [R^2 + 2(dR/d\phi)^2 - R \, d^2R/d\phi^2]/[R^2 + (dR/d\phi)^2]^{3/2}.$$

s can be eliminated from Equation (13) by using $s/\sin (\theta^* - \phi) = R/\sin (\theta^* - \phi + \psi)$. Equation (13) then becomes, after some reduction,

$$\theta^* = \tan^{-1} \{[\sin (\phi - \psi) + G \sin \phi]/[\cos (\phi - \psi) + G \cos \phi]\} \tag{14}$$

where $G = 1 - 2kR/\cos (\psi/2)$. Using Equation (12) gives

$$r^* = R \sin \psi / \sin (\theta^* - \phi + \psi). \tag{15}$$

Equations (14) and (15) are thus parametric (parameter ϕ) equations for the caustic.

Investigation of the caustics associated with the two limiting cases, $\beta \ll 1$ and $\beta \gg 1$, reveals the same qualitative behaviour as illustrated by Fig. 4. In each case, the caustic

separates regions in which reflected ions from either one or three surface points can contribute to the density. This results in a step function character for m, i.e., m has the value 1, 2, or 3 depending upon whether the point r, θ lies respectively interior to, on, or exterior to the caustic.

It is essential to have an analytic form for the caustic in order to solve numerically for the contours of constant density. A computer program was employed to find the roots of Equation (12) at about 300 $r - \theta$ lattice points interior to the cavity. On one side of the caustic, the program was devised to find only one root whereas on the other side three roots were found. Once the roots were found, the density was then calculated using Equations (11) and (12). Contours were then obtained by linearly interpolating a certain value through the lattice of density values. Graphs and detailed discussion of these contours will be deferred to Section 5.

A final problem remains, namely, consideration of the effects due to higher order reflections. The modifications involved are twofold. First of all, the shape of the contact discontinuity is modified. At the point where the caustic intersects the contact discontinuity as many as three contributions to the pressure may exist. Specifically, on the lower part of the surface, ions reflected from two upper surface points plus ions flowing directly from the nucleus are now available to exert pressure. One would expect the cavity to flare out due to the increased pressure. However, since pressure contributions fall off radially (direct ions) or as $1/y$ (reflected ions), where y is the distance from the axis, whereas the solar wind pressure has a constant value, eventually the boundary will tend toward a cylindrical form as was true of the original surface. Calculation shows that the flaring of the cavity is only about 5–10° and that the form rapidly returns to its original cylindrical shape. Note also that the assumption of no collisions between ions begins to fail after one or two reflections, especially due to the focusing of ions along the tail axis. Hence, for distances well into the tail the flow should be continuous and of constant density. The second modification is in the density. It is now found by superposing the density due to first and second order reflected ions and ions flowing directly from the nucleus. This problem is not treated analytically since, as mentioned, the validity of the model is questionable for second and higher order reflections.

5. APPLICATION OF THE MODEL TO ACTUAL COMETS

The outline around a comet's nucleus has been described as a parabola (Alfvén, 1957). Empirical curve fitting has shown that a catenary also approximates this boundary (Marochnik, 1963). Now the equation of the catenary, $x = 2a - a \cosh (y/a)$, can be expanded to give

$$x = a - [1/(2!\, a)]y^2 - [1/(4!\, a^3)]y^4 + \ldots \tag{16}$$

which, to first order, reduces to a parabola. The catenary probably gives a somewhat more accurate fit since it provides a second order correction. To compare the contour obtained here with these results, Equation (8) is expanded.

$$x = R_0 - [A/(2!\, R_0)]y^2 - [B/(4!\, R_0^3)]y^4 + \ldots \tag{17}$$

where

$$A = (4 - \varepsilon)/(6 - \varepsilon)$$

$$B = [3(4 - \varepsilon)^3 - 6\varepsilon(6 - 2\beta - 3\varepsilon)]/[(10 - \varepsilon)(6 - \varepsilon)^3]$$

$$\varepsilon = \exp(-\beta)/[1 - \exp(-\beta)].$$

Recall that β is a dimensionless parameter given by $\beta = R_0/v\tau$. Note that to first order Equation (17) also reduces to a parabola. Let $a = R_0/A$ in Equation (17). This equation then becomes

$$x = aA - [1/(2!\,a)]y^2 - [C/(4!\,a^3)]y^4 + \ldots \tag{18}$$

where $C = B/A^3$. As β varies from 0 to ∞, C varies from 1·3 to 1·8; hence, neglecting the constant term (which merely corresponds to a translation of the axes), Equation (18) closely approximates a catenary for all values of β. Figure 2 shows a parabola and catenary for comparison with the contours obtained here.

Note that all terms in Equation (16) and (18) are of even order. Hence, to third order, Equation (18) will still closely approximate the catenary. For large values of x, however, the catenary has an infinite width. Hence, only in the head region will the catenary fit the true boundary. Equation (18) not only provides an accurate fit to the cavity outline on the sunward side but also defines a curve with a finite width at infinity.

Figure 5 shows the density contours associated with the case $\beta \gg 1$ (or, equivalently, very large mass production rates). The unit of density, $\rho_0(R_0)$, can be found from Equation (3) using the values adopted for the physical parameters. Thus, $\rho_0(R_0) = 1500\, m_p/\text{cm}^3$ or about 500 ions/cm^3. Since the production rate and on-axis stopping distance change in such a way that Equation (3) always holds, the unit is the same for the case $\beta \ll 1$. It agrees reasonably well with the average value of 300 ions/cm^3 found by Wurm (1963) for the tail region of Halley's Comet.

In the head region the contours are roughly circular. As a contour is followed into the tail, a gradual straightening occurs. A discontinuity occurs across the caustic interior to which the contours again straighten as they are followed still further into the tail. Contours for the case $\beta \ll 1$ are qualitatively similar to those in Fig. 5.

The most striking feature of the model is the prediction of the caustic surface (the dashed curve in Fig. 5; see also Fig. 4). For steady state conditions, the distance in units of R_0 from the nucleus where this surface intersects the axis is given by $R^* = 4/(2 - \varepsilon)$. Thus R^* decreases monotonically from 4 to 2 as β varies from 0 to ∞. Moreover, as β varies through this same range, the distance from the nucleus (in units of R_0) to the point where

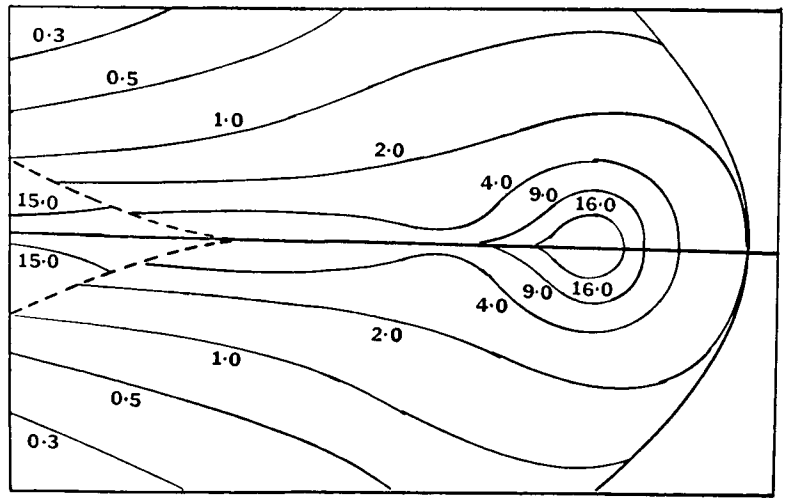

FIG. 5. CONTOURS OF CONSTANT DENSITY FOR THE CASE OF LARGE MASS PRODUCTION RATE.

the caustic intersects its associated contact discontinuity decreases from about 30 to 10. Since the density has a marked increase across this surface, it may correspond to an observable feature in a comet; the symmetry with respect to the axis is highly suggestive of the rays.

The model to this point has been developed assuming steady state conditions. However, it is well known that the production rate of neutrals can vary. Outbursts, for example, are generally regarded as being due to a sudden increase in the production rate of neutrals. Furthermore, as noted by Beard (1966), more uniform increases or decreases in the production rate may occur over extended periods of time. If more or less stratified layers rich in dust and ice exist, the production rate will decrease as an icy layer, rich in volatile molecules, is depleted.

A sudden increase in the production rate would, according to the model developed here, result in the apparent motion of matter along the caustic. That is to say, the density along the caustic would not increase instantaneously at all points to a new level due to the different path lengths associated with the ion trajectories reaching this surface. Rather, the increase would first occur at the point closest to the nucleus and move outward. If the outburst were localized in a short time interval, there would be an actual motion of the increased density along the caustic giving the illusion that matter in a localized region was in motion. Moving clouds or condensations might be accounted for by this mechanism.

A final phenomenon the proposed model may explain is the rotation of the rays. As previously noted, the distance of the caustic from the axis depends upon the on-axis stopping distance which, in turn, depends upon the production rate of neutrals. Thus, larger production rates correspond to closer distances to the axis. If, indeed, the caustic is a ray, an increase or decrease in production rate would result in inward or outward rotation respectively.

6. SUMMARY AND CONCLUSIONS

The major assumptions of the present model are that ions move away from a comet's nucleus independently of one another and that they are specularly reflected from the interface separating cometary material from the solar wind. Utilizing these assumptions, a model was developed which predicted the size and shape of the contact discontinuity and the plasma density interior to it. In addition, the model predicted the existence of structure in a comet's tail. Previous models, which have treated the outflowing ions as a continuous medium, give solutions for the density which show no pronounced irregularities.

The present model is able to account for the observed outline of the contact discontinuity and for the finite width of the tail. The predicted mean ion density agrees well with Wurm's (1963) value based upon the intensity of radiation scattered from the tail ions. Plausibility arguments (Section 5) show that certain time dependent phenomena, in particular the motion of clouds or condensations and the collapsing of the rays, may be explainable in terms of the model.

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